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Research Document 2009/054 | **Document de recherche 2009/054**

Optical, chemical, and biological oceanographic conditions in the Maritimes Region in 2008

Propriétés optiques, chimiques et biologiques de l'océan dans la région des Maritimes, en 2008

G. Harrison[1], C. Johnson[1], E. Head[1], J. Spry[1], K. Pauley[1], H. Maass[1], M. Kennedy[1], C. Porter[1], and V. Soukhovtsev[2]

[1]Ocean Research and Monitoring Section, Ecosystem Research Division
Bedford Institute of Oceanography
Box 1006, 1 Challenger Drive
Dartmouth, Nova Scotia
B2Y 4A2

[2]Coastal Oceanography Section, Ocean Sciences Division
Bedford Institute of Oceanography
Box 1006, 1 Challenger Drive
Dartmouth, Nova Scotia
B2Y 4A2

ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

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Correct citation for this publication:
La présente publication doit être citée comme suit :

Harrison, G., C. Johnson, E. Head, J. Spry, K. Pauley, H. Maass, M. Kennedy, C. Porter, and V. Soukhovtsev. 2009. Optical, chemical, and biological oceanographic conditions in the Maritimes Region in 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/054. vi + 55 p.

ABSTRACT

Optical, chemical, and biological oceanographic conditions in the Maritimes Region (Georges Bank, eastern Gulf of Maine, Bay of Fundy, and the Scotian Shelf) during 2008 are reviewed and related to conditions during the preceding year and over the longer-term, where applicable. In addition to descriptions of Atlantic Zonal Monitoring Program (AZMP) core data collections (fixed stations, seasonal sections, ecosystem trawl or groundfish surveys, remote-sensing), some data from outside the region are discussed also to provide the larger, zonal perspective.

Optical properties at the Maritimes fixed stations in 2008 differed by site but were, for the most part, comparable to conditions observed in previous years. The most notable features in physical structure of the water column in 2008 were the slightly stronger stratification and shallower summer mixed layers at Halifax-2.

Wintertime nutrient inventories in surface waters at Halifax-2 were above average in 2008, while they were at normal levels at Prince-5. Deep (>50 m) nutrient inventories in spring were higher than normal, shelf-wide. Summer surface and deep nutrient inventories were below average.

The record high and widespread spring bloom seen on the Scotian Shelf in 2007 did not recur in 2008. In fact, spring chlorophyll levels were at or below normal. On the other hand, fall chlorophyll levels were above average on the western shelf in 2008. Phytoplankton community structure at the 2 fixed stations in 2007 was similar to that seen in previous years with diatoms dominating during the spring bloom and flagellates dominating in summer-fall at Halifax-2 and diatoms dominating the community at Prince-5 year-round.

In 2008, zooplankton biomass and *Calanus finmarchicus* abundance both exhibited late peaks of near-average magnitude at Halifax-2 and both were above average in the summer. High *C. finmarchicus* abundance persisted in the fall. Two numerically dominant small copepod species, *Pseudocalanus* spp. and *Oithona similis*, and the shallow water copepod *Temora longicornis*, were more abundant than average on the eastern Scotian Shelf. At Halifax-2, cold water *Calanus* species (*C. hyperboreus* and *C. glacialis*) were more abundant than average, while warm water shelf species (*Centropages typicus* and *Paracalanus* spp.) were less abundant than normal. However, these trends were reversed on the Scotian Shelf. At Prince-5, zooplankton biomass and copepod abundance exhibited an earlier than average peak, which was dominated by offshore species such as *Pseudocalanus* spp. and *Calanus finmarchicus*. The copepod community at Prince-5 was dominated by offshore species in 2008, especially in the summer. The abundance of *Limacina* spp., a species susceptible to ocean acidification, remained low on the eastern Scotian Shelf and was close to average on the western Scotian Shelf.

RÉSUMÉ

On examine les conditions océanographiques optiques, chimiques et biologiques dans la région des Maritimes (banc Georges, secteur est du golfe du Maine, baie de Fundy et plateau néo-écossais) au cours de 2008, puis on les compare aux conditions observées au cours de l'année précédente et à long terme, s'il y a lieu. En plus des descriptions des séries de données de base du Programme de monitorage de la zone atlantique (PMZA) [stations fixes, transects saisonniers, relevés au chalut de l'écosystème ou du poisson de fond, télédétection], on examine un certain nombre de données de l'extérieur de la région afin de donner une vue d'ensemble de la zone.

Les propriétés optiques aux stations fixes de la région des Maritimes en 2008 différaient d'un endroit à l'autre, mais, en général, étaient comparables aux conditions observées les années précédentes. Les caractéristiques les plus remarquables de la structure physique de la colonne d'eau en 2008 étaient la stratification légèrement plus prononcée et les couches de mélange d'été moins profondes à Halifax 2.

Les concentrations d'éléments nutritifs au cours de l'hiver dans les eaux de surface à Halifax 2 étaient supérieures à la moyenne en 2008, tandis qu'ils étaient normales à Prince 5. Les concentrations d'éléments nutritifs en profondeur (>50 m) au printemps étaient plus élevées que la moyenne à l'échelle du plateau. Les concentrations d'éléments nutritifs en surface et en profondeur étaient plus faibles que la moyenne au cours de l'été.

Le maximum record de l'amplitude de la prolifération printanière sur le plateau néo-écossais de 2007 ne s'est pas reproduit en 2008. En fait, les niveaux de chlorophylle au printemps étaient égaux ou inférieurs à la moyenne. En revanche, les niveaux de chlorophylle à l'automne étaient supérieurs à la moyenne sur l'ouest du plateau néo-écossais en 2008. La structure de la communauté du phytoplancton aux deux stations fixes en 2007 était semblable à celle observée au cours d'années précédentes avec la domination de diatomées au cours de l'efflorescence printanière de flagellés au cours de l'été et de l'automne à Halifax 2 et de diatomées dans la communauté à Prince 5 toute l'année.

En 2008, la biomasse du zooplancton et l'abondance de *Calanus finmarchicus* ont affiché des périodes de pointe tardives d'une importance près de la moyenne à Halifax 2 et les deux étaient supérieures à la moyenne pendant l'été. L'abondance élevée de *C. finmarchicus* s'est poursuivie à l'automne. Deux petites espèces de copépodes dominantes en nombre, *Pseudocalanus* spp. et *Oithona similis*, ainsi que le copépode d'eau peu profonde, *Temora longicornis*, étaient plus abondantes que la moyenne dans l'est du plateau néo-écossais. À Halifax 2, l'espèce d'eau froide *Calanus* (*C. hyperboreus* et *C. glacialis*) était plus abondante que la moyenne, tandis que l'espèce d'eau chaude (*Centropages typicus* et *Paracalanus* spp.) était moins abondante que la moyenne. Cependant, ces tendances étaient renversées dans le plateau néo-écossais. À Prince 5, la biomasse du zooplancton et l'abondance de copépodes ont affiché une période de pointe plus précoce que la moyenne et ces espèces étaient dominées par des espèces pélagiques telles que *Pseudocalanus* spp. et *Calanus finmarchicus*. La communauté de copépodes à Prince 5 était dominée par les espèces pélagiques en 2008, particulièrement en été. L'abondance de *Limacina* spp., une espèce sensible à l'acidification des océans, est demeurée faible dans l'est du plateau néo-écossais et près de la moyenne dans l'ouest du plateau néo-écossais.

INTRODUCTION

The Atlantic Zonal Monitoring Program (AZMP) was implemented in 1998 (Therriault et al. 1998) with the aim of: (1) increasing Department of Fisheries and Oceans' (DFO's) capacity to understand, describe, and forecast the state of the marine ecosystem and (2) quantifying the changes in ocean physical, chemical, and biological properties and the predator-prey relationships of marine resources. A critical element in the observational program of AZMP is an annual assessment of the distribution and variability of nutrients and the plankton they support.

A description of the distribution in time and space of nutrients dissolved in seawater (nitrate, silicate, phosphate, oxygen) provides important information on the water-mass movements and on the locations, timing, and magnitude of biological production cycles. A description of the distribution of phytoplankton and zooplankton provides important information on the organisms forming the base of the marine foodweb. An understanding of the production cycles of plankton is an essential part of an ecosystem approach to fisheries management.

The AZMP derives its information on the state of the marine ecosystem from data collected at a network of sampling locations (fixed point stations, cross-shelf sections, trawl surveys) in each region (Quebec, Maritimes/Gulf, Newfoundland) sampled at a frequency of bi-weekly to once annually. The sampling design provides for basic information on the natural variability in physical, chemical, and biological properties of the Northwest Atlantic continental shelf. Trawl (groundfish) surveys and cross-shelf sections provide detailed geographic information (Harrison et al. 2005), but are limited in their seasonal coverage. Critically placed fixed stations complement the geography-based sampling by providing more detailed information on temporal (seasonal) changes in ecosystem properties.

Reviewed here are the optical, chemical, and biological oceanographic conditions in the Maritimes Region, including the Georges Bank/Gulf of Maine/Bay of Fundy system and the Scotian Shelf, during 2008. Conditions in 2008 will be compared with those observed during recent years (Harrison et al. 2008) and over the longer-term where historical information is available.

METHODS

To the extent possible, sample collection and processing conforms to established standard protocols (Mitchell 2002). Non-standard measurements or derived variables are described.

Sample Collection

Maritimes/Gulf AZMP sea-going staff participated in 6 missions (seasonal section cruises and trawl surveys) during the 2008 calendar year, in addition to repeat day-trips to the 3 fixed stations; 654 station occupations were the total sampled all together (Table 1).

Fixed stations. In 2008, the Maritimes/Gulf regions' 3 fixed stations, Shediac Valley, Halifax-2, and Prince-5 (Figure 1), were sampled on a minimum monthly basis (Prince-5) with attempted semi-monthly sampling during the spring bloom period. As always, the availability of resources (platforms) and, to some extent, difficulties with weather and ice, make achieving this sampling frequency a challenge. In 2007, Halifax-2 and Prince-5 were sampled on 18 and 12 occasions, respectively. Shediac was sampled only 8 times. By definition; the Shediac station has an ice-truncated open water season. Difficulties encountered with Coast Guard operations and platform availability in the previous years were somewhat resolved, and Shediac station

occupations were consistent with those of recent years. Fixed station occupations were, once again, below the highest frequency in 2002.

The standard sampling suite when occupying the fixed stations consists of:

- CTD (Conductivity, Temperature, Depth) (SBE25) profile including electronic sensing of pressure, temperature, conductivity, dissolved oxygen, fluorescence, and PAR (Photosynthetically Active Radiation) as the common suite,
- Niskin water bottle samples at standard depths for nutrient, calibration salinity, calibration oxygen, and chlorophyll analyses as the minimum suite of measurements,
- Niskin water bottle sample for phytoplankton enumeration,
- Vertical ring net tows (200 µm mesh net) for zooplankton biomass (wet weight) and enumeration, and
- Secchi depth measurement when possible.

Shelf sections. Four primary transects (Browns Bank Line, Halifax Line, Louisbourg Line, Cabot Strait Line; Figure 1), and a number of additional lines/stations (Figure 2) are sampled seasonally in spring (April/May) and fall (October/November). An additional occupation of the Halifax Line is also attempted in May-July period as part of the Labrador Sea program in the Maritimes Region. In 2008, the spring and fall missions were carried out from the *CCGS Hudson*; so the potential was there to carry out the normal/full sampling campaign. Unfortunately, ship problems curtailed the Spring Halifax section allowing occupation of only 3 of 7 stations. The 4 core transects were occupied in the both seasons. There was an opportunity to sample the Halifax Line in June 2008, as the field-time allotted to the Labrador Sea mission allowed sufficient time to occupy the section. Five new deep-water stations added to the Halifax line were sampled at that time, as well.

The standard sampling suite when occupying section stations consisted of:

- CTD (SBE911 OSD Rosette) profile including electronic sensing of pressure, temperature, conductivity, dissolved oxygen, fluorescence, and PAR,
- Niskin water bottle samples at standard depths for nutrient, calibration salinity, calibration oxygen, POC (Particulate Organic Carbon), and plant pigment analyses (chlorophyll, HPLC [High Pressure Liquid Chromatography], absorbance),
- Niskin water bottle sample for phytoplankton enumeration, and
- Vertical ring net tows (200 µm mesh net) for zooplankton biomass (wet weight) and enumeration.

Trawl (groundfish) surveys. There are 4 primary trawl surveys in which AZMP-Maritimes/Gulf participates: the late winter (February) Georges Bank survey, the spring (March) eastern Scotian Shelf survey, the summer (July) Scotian Shelf/eastern Gulf of Maine survey, and the fall (September) southern Gulf of St. Lawrence survey (Figure 3). These surveys were all carried-out in 2008 by DFO's Population Ecology Division (PED) with AZMP participation. In 2008, there was an attempt to add a late winter (March) survey for the western Scotian Shelf similar in scope to the start of the summer groundfish survey. Extreme weather and vessel problems resulted in an abbreviated version of that program being combined with the Georges Bank mission.

The standard sampling suite when occupying trawl survey stations consisted of:

- CTD (SBE25) profile including electronic sensing of pressure, temperature, conductivity, dissolved oxygen, fluorescence, and PAR (photosynthetically active radiation),

- Niskin water bottle samples at surface (5 m) and near bottom depths (as a minimum, but 25 m and 50 m samples taken when possible) for nutrient, calibration salinity, calibration oxygen, and chlorophyll analyses,
- Niskin water bottle samples for phytoplankton enumeration taken at fixed station sites only,
- Vertical ring net tows (200 µm mesh net) for zooplankton biomass (wet weight) and enumeration at a subset of stations (see Figure 3), and
- Sea surface temperature recorder, trawl mounted depth/temperature recorders.

Deployment

CTD. The CTD is attached to the end of a hydrographic wire (or conducting cable for the rosette system) and lowered at ~0.3 m/sec for the portable SBE25 (~0.83 m/sec for the higher resolution SBE911 ship's rosette) to within 2 m of the bottom when possible.

Standard depths for water samples:
- Fixed-stations:
  1. Halifax-2: 1, 5, 10, 20, 30, 40, 50, 75, 100, 140 m.
  2. Shediac: 1, 5, 10, 20, 30, 40, 50, 60, 70, 80 m.
  3. Prince-5: 1, 10, 25, 50, 95 m.
- Seasonal sections – near-surface: 10, 20, 30, 40, 50, 60, 80, 100, 250, 500, 1000, 1500, 2000 m (depth dependent).
- Trawl surveys: 5, 25, 50 m, near bottom (when possible).

Net tows. Ring nets of a standard 202u mesh are towed vertically from near bottom to surface at ~1 m/sec. In deep offshore waters, maximum tow depth is 1000 m. The net is hosed carefully and sample collected from the cod-end, then preserved in buffered formalin.

Secchi depth. The Secchi disc is lowered slowly and the depth where it can no longer be visually detected is recorded.

Optical Properties

Optical properties of the seawater (attenuation coefficient, photic depth) were derived from one or more of, (a) in-water light extinction measurements using a CTD-rosette mounted PAR (photosynthetically active radiation) meter, (b) Secchi depth, and (c) chlorophyll biomass profile, according to the following procedures:

1. The downward vertical attenuation coefficient for PAR ($K_{d\text{-}PAR}$) was estimated from the linear regression of $\ln(E_d(z))$ versus depth z (where $E_d(z)$ is the value of downward irradiance at z m) in the depth interval from minimum depth to 50 m (minimum depth is typically around 2 m and is always less than 6 m).

2. The value of K_d from Secchi disc observations was found using:

$$K_{d\_secchi} = 1.44/Z_{sd}\ (m^{-1})$$

where Z_{sd} = depth in m at which the Secchi disc disappears from view. The estimate of euphotic depth was made using the following expression:

$$Z_{eu}\ (m) = 4.6 / K_d$$

Reference values were calculated from all estimates of $K_{d\text{-}PAR}$ and K_{d_secchi}.

3. The value of Kd from chlorophyll biomass profile observations was calculated as:

$$K_{d\_chla} = 0.027 + 0.015 + 0.04^{*}B_{exp}\ (m^{-1}) \qquad \text{(Platt et al. 1988)}$$

where B_{exp} is the observed values of chlorophyll a concentration B(z) (in mg m^{-3}) for depth interval from zero to z_e, the depth where the downwelling irradiance is 36.79% (e^{-1}) of the surface value. Chlorophyll observations were linearly interpolated each 0.25 m to calculate B_{exp}; K_{d_chla} was calculated over the interval 0 to z_e from:

$$E_d(0)^{*}\exp(-K_{d\_chla}{}^{*}z_e) = (1/e)^{*}\ E_d(0), \text{ i.e.}$$

$$K_{d\_chla}{}^{*}z_e = \Sigma\ (0.027 + 0.015 + 0.04\ ^{*}\ B(z_i))^{*}dz_i = 1$$

Integrated chlorophyll for the depth intervals 0–50 m and 0–100 m (0–80 m for the Shediac fixed station) were calculated as the sum of products Chl_i * dd_i , where Chl_i is chlorophyll concentration measured for the depth z_i and dd_i is the depth interval around z_i: $dd_i = 0.5^{*}(z_{i+1} - z_{i-1})$.

Mixed-layer and Stratification Index

Two simple indices of the physical structure (vertical) of the water-column were computed for comparison with optical properties; mixed-layer and stratification.

1. The mixed layer depth was determined from the observations of the minimum depth where the density gradient ($gradient_z$(sigma-t)) was equal to or exceeded 0.01 (kg m^{-4}).

2. The stratification index ($Strat_{Ind}$) was calculated as:

$$Strat_{Ind} = (\text{sig-t}_{50} - \text{sig-t}_{zmin})/(50 - z_{min})$$

where sig-t_{50} and sig-t_{zmin} are interpolated values of sigma-t for the depths of 50 m and z_{min} (the minimum depth of reliable CTD data); typically z_{min} is around 5 m and always less then 9 m.

Continuous Plankton Recorder (CPR)

Results from the Continuous Plankton Recorder (CPR) surveys are reported, starting this year, in a separate Research Document (Head and Pepin 2009).

Satellite Remote-sensing of Ocean Colour

Phytoplankton biomass was also estimated from ocean colour data collected by the Sea-viewing Wide Field-of-view (SeaWiFS) satellite sensor launched by NASA (National Aeronautics and Space Administration) in late summer 1997 (http://seawifs.gsfc.nasa.gov/SEAWIFS.html), and the Moderate Resolution Imaging Spectroradiometer (MODIS) "Aqua" sensor (http://modis.gsfc.nasa.gov/). The MODIS data stream began in July 2002. Satellite data do not provide information on the vertical structure of phytoplankton in the water column, but do provide synoptic information on their geographical distribution in surface waters at the large scale. Twice monthly composite images (based on MODIS 1.5 km spatial resolution data) of surface chlorophyll for the entire Northwest Atlantic (39-62.5 N Lat., 42-71 W Lon.) are routinely produced and posted (http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/seawifs/seawifs

3.html). Basic statistics (mean, range, standard deviation, etc.) are extracted from weekly composites (based on SeaWiFS 4 km spatial resolution data) for selected sub-regions (Figure 5), for the fixed stations and for the seasonal sections. Operational problems with the SeaWiFS sensor data acquisition and navigation systems resulted in gaps in the 4 km data product for the first 12 weeks (January-March) and 6 weeks in summer (July-mid August) of 2008.

As in 2007, oceanographic conditions at the Shediac fixed station and conditions observed during the September southern Gulf of St. Lawrence trawl survey will be reported by the Quebec Region in order to better consolidate regional (i.e. entire Gulf of St. Lawrence) observations and interpretation.

RESULTS

Mixing and Optical Properties

Mixing and optical properties of the upper water column varied by season and location at the Maritimes fixed stations (figures 6 and 7). Seasonal development of the mixed-layer and upper water-column stratification were most evident at the Halifax-2 station (Figure 6); shallow mixed layers (<20 m) and maximum stratification (>0.09 kg m^{-4}) were evident in late summer and early fall months (August-October). Mixed-layer development at Halifax-2 in 2008 was consistent with the long-term average conditions. Winter mixed layers depths were slightly deeper (~60 m) than the long-term mean (~50 m), while mixed layers in summer and fall were significantly shallower (<10 m) than the norm (>10-20 m). The development of stratification at Halifax-2 was also consistent with the long-term average, however, conditions in the summer and fall of 2007 were higher than usual and on an annual basis, average stratification at this station was the highest seen in the 10-year (1999-2008) data record. In marked contrast to the Halifax-2 station, stratification was extremely low (<0.01 kg m^{-4}) at the Prince-5 station throughout the year, due principally to strong tidal mixing. Mixed-layer depths are highly variable and difficult to determine at this station due to the very small vertical density differences (see Methods Section); estimates normally range from ~30-40 m in spring and early summer to almost full depth in winter. In 2008, mixed layer depths were too variable to discern a pattern at Prince-5, although on an annual basis, average MLD (Mixed Layer Depth) was shallower than normal.

Euphotic zone depth estimates derived from Secchi disc readings and direct downwelling irradiance (PAR) measurements were comparable (Figure 7). Maximum vertical light attenuation (and shallowest euphotic zone depths) normally coincide with the spring bloom and euphotic depths are generally deepest immediately following the decline of the bloom; this was evident at the Halifax-2 station. Overall, euphotic depths in 2008 were slightly shallower than the normal range (45-50 m) at Halifax-2. At the Prince-5 station, euphotic depths in 2008 were considerably shallower (~20 m) than at Halifax-2, remarkably constant through the year and consistent with the long-term average at that station. Overall, seasonal patterns and magnitudes of optical properties in 2008 at Halifax-2 and Prince-5 were similar to those observed in previous years.

Nutrients

Fixed stations. Distributions of the primary dissolved inorganic nutrients (nitrate, silicate, phosphate) included in the observational program of AZMP strongly co-vary in space and time (Petrie et al. 1999). For that reason and because the availability of nitrogen is most often associated with phytoplankton growth limitation in our coastal waters (DFO 2000), emphasis in this report will be placed on variability in nitrate concentrations.

A clear spring/early summer biologically-mediated reduction in near surface nitrate concentrations was seen at both Maritimes fixed stations in 2008 (Figure 8). Low surface values persisted throughout the summer/fall at Halifax-2, and concentrations did not increase at the surface again until late fall. The zone of nitrate depletion (i.e. defined as depths where concentrations were ≤ 1 mmol m^{-3}) in summer 2008 at Halifax-2 (33 m) was close to the long-term average (34 m). The seasonal evolution of the vertical nitrate structure at Halifax-2 in 2008 was similar to that observed in previous years, although the period of most rapid draw-down appeared to occur later than usual (i.e. April rather than March). Near surface nitrate concentrations at Prince-5 in 2008 were never reduced below 2 mmol m^{-3}. The period of most rapid biological draw-down at Prince-5 in 2008 (May) was comparable to the long-term average.

Strong seasonal variability in nitrate inventories of the upper 50 m (depth zone over which nutrient dynamics are strongly influenced by biological processes) is evident at both of the Maritimes fixed stations (figures 9a,b). Although the seasonal pattern of variability in nitrate at Halifax-2 in 2008 was similar to that observed in previous years, winter inventories were higher (by 30 mmol m^{-2}) than the norm (~250 mmol m^{-2}) and summer inventories lower (by 35 mmol m^{2}) than the norm (by 65 mmol m^{-2}) (Figure 9a, top 2 panels). Winter nitrate inventories in the upper 50 m at Prince-5 in 2008 were similar to the long-term average (~470 mmol m^{-2}) but, like Halifax-2, summer levels were lower (by 65 mmol m^{-2}) than the norm (~210 mmol m^{-2}) (Figure 9b, top 2 panels). At both fixed stations, summer nitrate inventories in the upper 50 m were the lowest seen since observations began in 1999. Winter nitrate inventories in deep waters (>50 m) at Halifax-2 and Prince-5 in 2008 were generally comparable with the long-term averages: Halifax-2 (~720 mmol m^{-2}), Prince-5 (~470 mmol m^{-2}) (figures 9a,b, bottom 2 panels). However, summer inventories in deep waters were below (by 160 mmol m^{-2} at Halifax-2 and 30 mmol m^{-2} at Prince-5) the norm (~910 mmol m^{-2} at Halifax-2, ~270 mmol m^{-2}) at both stations. Annual anomalies of near surface nitrate suggest that inventories have been relatively steady and slightly above the norm for the past several years at Halifax-2, whereas annual anomalies of deep water nitrate have shown considerable interannual variation with levels slightly below the norm for the past 2 years; lowest levels were seen in 2005 (Figure 9a). Because of strong vertical mixing at Prince-5, annual surface and deep water nitrate anomalies show the same patterns of relatively high interannual variability; levels have been at or slightly above the average for the past 3 years (Figure 9b). No long-term trend in nitrate inventories has been seen at either fixed station.

Shelf sections. Vertical distributions of nitrate in spring were generally similar along the Scotian Shelf sections in 2008, i.e. concentrations were low (<2 mmol m^{-3}) in near surface waters (<50 m), as a result of phytoplankton consumption, and increased with depth (Figure 10); the exception was along the Cabot Strait line where surface concentrations generally exceeded 2 mmol m^{-3} except at the 2 northern-most stations. Deep-water (>50 m) concentrations were highest in basins (>20 mmol m^{-3}) and in slope waters off the edge of the shelf. As in previous years, nitrate levels in surface waters were already reduced at the time of the spring survey in April (1 mmol m^{-3} depth horizon: ~20-50 m). Likewise, surface nitrate concentrations were still low during the fall survey in October (1 mmol m^{-3} depth horizon: ~20-50 m), showing little evidence of seasonal mixing of nutrients from depth into surface waters. Despite similarities to the norm in vertical structure in 2008, nitrate inventories in the upper 50 m in 2008 were higher (by 50-60 mmol m^{-2}) along all lines in spring compared to previous years (Figure 11a, Table 2); levels were highest or second highest seen since observations began in 1999. Similarly, surface inventories were at record higher levels (by 40-60 mmol m^{-2} above the norm) in fall on the western shelf (Halifax and Browns Bank lines); fall surface inventories, however, were slightly lower than the norm (by 30 mmol m^{-2}) on the Louisbourg line in fall. Deep (>50 m) nitrate inventories were higher than normal (by 70-100 mmol m^{-2}) on the Louisbourg and Halifax lines

in spring and Halifax line in fall; deep inventories on the Louisbourg line were below average (by >100 mmol m^{-2}) in fall (Figure 11b). Deep nitrate inventories along the Cabot Strait and Browns Bank lines were at normal levels in spring and fall 2008. There is a suggestion of progressively increasing near surface inventories of nitrate on the Louisbourg and Halifax lines since approximately 2003, but not on the Cabot Strait and Browns Bank lines (Figure 11a); there are no discernable trends in deep nitrate inventories for any of the lines over the 10-year time series (Figure 11b).

Trawl (groundfish) surveys. Bottom water nitrate concentrations on the Scotian Shelf in July 2008 (Avg: 10.3 mmol m^{-3}) were below the long-term average, 11.4 mmol m^{-3} (Table 3) and consistent with observed low summer deep water (>50 m) nitrate inventories at the Halifax-2 fixed station. Concentrations increased with water depth with highest levels observed in the deep basins on the shelf (e.g. Emerald Basin) and in slope waters off the shelf edge (Figure 12). Bottom water oxygen saturation on the Scotian Shelf in summer 2008 (Avg: 79% sat), in contrast, was comparable to the long-term average (Table 3). However, the area of the bottom covered by waters with <60% saturation was somewhat lower (11,800 km^2 or 7.8% of the shelf area) than the long-term average (13,900 km^2 or 9.2% of the shelf area). As usual, lowest saturations were found in deep basins (e.g. Emerald Basin) and deep waters off the shelf edge where nutrients are highest. There is no discernable trend in bottom water nitrate concentrations nor oxygen content on the Scotian Shelf over the time series.

Phytoplankton

Fixed stations. Distinctly different seasonal phytoplankton growth cycles are evident at the 2 Maritimes fixed stations (figures 13 and 14). The record high spring bloom observed at Halifax-2 in 2007 (>900 mg m^{-3}) was not seen in 2008; indeed, the 2008 bloom (267 mg m^{-3}) was significantly smaller then the long-term average (~500 mg m^{-3}). Annual chlorophyll anomalies at Halifax-2 have been relatively stable over the past 10 years and show no discernable trend (Figure 14, top 2 panels). A more detailed analysis of the bloom at this station suggested that the timing in 2008 (YD [Year Day] 106) was 11 days later than normal (YD 95) (Figure 15a). In addition, the duration of the bloom was somewhat shorter (32 days) than the long-term average (45 days). Besides changes in bloom dynamics, the "background" chlorophyll levels (outside the bloom period) have been generally declining over the past 10 years, from ~39 mg m^{-2} in 1999 to ~27 mg m^{-2} in 2006, although levels have increased slightly over the past 2 years (Figure 15b). The evolution of the phytoplankton community composition at Halifax-2 in 2008 was broadly similar to that seen previously, i.e. diatoms dominated in the winter/spring, i.e. >75% of the total count, and flagellates and dinoflagellates dominated (>60% of the total count) the rest of the year (Figure 16). In 2008, however, the contribution of diatoms to the microplankton community at the peak of the spring bloom comprised almost 100% of the community (usually ~90%), but immediately following the bloom fell to <10% (normally ~30%) and increased again in the fall to >60% (normally ~30%). During the post-bloom period in 2008, flagellates accounted for >80% of the microplankton (normally 60%) with low percentages in the fall (~20% as opposed to the normal 40-60%).

The phytoplankton growth cycle at Prince-5, in contrast to Halifax-2; is characterized by a primary burst of growth in summer (June) with secondary peaks in late summer or fall (August-September) (figures 13 and 14). Annual chlorophyll anomalies at Prince-5, as the case for Halifax-2, have been relatively stable over the past 10 years and show no discernable trend (Figure 14, bottom 2 panels). In 2008, the peak concentration (496 mg m^{-2}), occurring on YD 162, was comparable in magnitude (426 mg m^{-2}) and timing (YD 162) with the long-term average. However, the duration of the primary bloom (61 days) was shorter than the long-term average (72 days). As has been noted previously, the phytoplankton community at Prince-5 is

comprised almost exclusively of diatoms (>95%) year-round (Figure 16). On an annual basis, Prince-5 sustains the larger chlorophyll inventories of the 2 Maritimes fixed stations (P-5: 107 mg m^{-2}, Halifax-2: 79 mg m^{-2}).

Shelf sections. Chlorophyll levels along all the shelf sections are always considerably higher in spring than in fall. Particularly noteworthy during the spring 2008 survey was the overall low chlorophyll levels at the southern stations of the Cabot Strait line and inner stations of the Browns Bank line and the low surface values at the inner Louisbourg line stations and outer Browns Bank line stations (Figure 17). Although chlorophyll levels >6 mg m^{-3} were observed during the spring survey, inventories (0-100 m) were considerably lower (~100-190 mg m^{-2}) than normal (~250-370 mg m^{-2}) along 3 of the 4 lines (Cabot Strait, Louisbourg, and Browns Bank) (Figure 18, Table 2). In contrast, chlorophyll inventories during the fall surveys were above (~40-60 mg m^{-2}) average levels (~30-50 mg m^{-2}) on the western shelf (Halifax and Browns Bank lines). High interannual variability has characterized spring chlorophyll inventories along all lines and no clear trend has been discernable. In contrast, fall inventories have been much less variable and have been trending downward over the years.

Trawl (groundfish) surveys. Near-surface chlorophyll levels during the 2008 spring survey on the eastern Scotian Shelf showed a distributional pattern similar to that seen in previous years, i.e. high concentrations were seen off-shelf (>4 mg m^{-3}) and distributed generally west of Sable Island (Figure 19). Surface chlorophyll levels during the summer Scotian Shelf survey, on the other hand, were uniformly low (<1 mg m^{-3}) over the central and outer shelf. Elevated concentrations (>1 mg m^{-3}) were only observed near the coast off SW Nova Scotia and approaches to the Bay of Fundy, as observed in previous years. These areas are generally characterized by strong vertical mixing. Overall, summer surface chlorophyll concentrations on the Scotian Shelf in 2008 (0.64 mg m^{-3}) were similar to the long-term average of 0.68 mg m^{-3} (Table 3). There is no discernable trend in shelf-wide chlorophyll concentrations over the 10-year time series.

Satellite ocean colour. Satellite ocean colour (SeaWiFS and MODIS) data provide a valuable alternative means of assessing surface phytoplankton biomass (chlorophyll) at the AZMP fixed stations, along the seasonal sections, and at larger scales (Northwest Atlantic) and have the potential to provide temporal data and synoptic spatial coverage not possible from conventional sampling. Two-week composite images of the Maritimes Region covering the major periods of the shelf section surveys (Figure 20) and trawl surveys (Figure 21) put those operations into a larger geographic context and reveal features that supplement/corroborate ship-based observations or provide information not otherwise attainable. For example, the off-shelf maximum in surface chlorophyll observed during the early March eastern Scotian Shelf trawl survey was seen in the satellite imagery (Figure 21). In a similar way, the imagery shows the contrast in surface chlorophyll levels between spring (April) and fall (October) of the shelf line surveys (Figure 20). Noteworthy also was the uncharacteristically low chlorophyll levels on the southern end of the Cabot Strait line observed during the spring survey (Figure 17). Similarly, the images show the overall low surface chlorophyll levels and enhanced levels off Yarmouth and the mouth of the Bay of Fundy observed during the July trawl survey (Figure 21).

An equally informative application of the satellite-based chlorophyll fields is to generate graphical representations of the seasonal chlorophyll dynamics along the shelf sections (Figure 22). It is evident from the satellite-data, for example, that surface chlorophyll concentrations are generally higher on the eastern Scotian Shelf than on the central and western shelf; spring levels along all lines were particularly high in 2007. The dynamics of the onset, duration and termination of the spring and fall blooms are also revealed in this type of graphical presentation as well as spatial (across-shelf) relationships. For example, it is apparent that the spectacular

shelf-wide bloom of 2007 was not repeated in 2008; indeed, it is hard to detect a spring bloom at all along the Cabot Strait and Browns Bank lines from this representation and the blooms along the Louisbourg and Halifax lines were only apparent on the inner shelf.

At the larger scale (i.e. statistical sub-regions in the Maritimes Region, see Figure 5), the timing and duration of the spring bloom in 2008 compared with previous years in most regions (Figure 23). One noteworthy exception was the absence of a spring bloom in Cabot Strait as noted previously. Also, the satellite data suggested slightly higher levels of surface chlorophyll in the fall on the western Scotian Shelf than seen previously, consistent with the line survey data (Figure 18, Table 2). On an annual basis, no clear trend has been detected in any of the satellite products over the time period of observations (1998-2008).

Continuous Plankton Recorder (CPR). The CPR is the longest data record available on plankton in the Northwest Atlantic (see Figure 4). CPR data analysis lags AZMP reporting by one year; thus, only data up to 2007 are currently available. Phytoplankton colour index (PCI) and abundance trends of large diatoms and dinoflagellates have been reported by Head and Pepin (2009).

Zooplankton

Fixed stations. The climatological seasonal cycles of zooplankton biomass and abundance are very different at the Halifax-2 and Prince-5 fixed stations. At Halifax-2, the annual peak in abundance and biomass occurs in April to May, and zooplankton abundance and biomass remain relatively high during the fall and winter (biomass, Figure 24; abundance, Harrison et al., 2008). At Prince-5, zooplankton abundance is about an order of magnitude lower in the late fall and winter than at Halifax-2 (Harrison et al, 2008), and biomass exhibits a similar but less extreme pattern (Figure 24). The timing of peak abundance and biomass is variable at Prince-5, with climatological average peaks in July and September. In 2008, the seasonal cycle of zooplankton biomass at Halifax-2 deviated from the climatological seasonal cycle (1999-2007) and exhibited 2 peaks, the first, smaller peak in April and a second, larger peak in early July, rather than a single peak in April-May (Figure 24). The second zooplankton biomass peak was similar in magnitude to the climatological average peak biomass (Figure 24), but it was slightly lower than average compared to peak values in previous years (Figure 33). The annual average zooplankton biomass anomaly at Halifax-2 in 2008 was similar to 2002, the lowest observed value in the 10-year time series, primarily driven by anomalously low spring-time values (Figure 25a). At Prince-5, the magnitude of the zooplankton biomass peak in 2008 was similar to the climatological peaks in June and September (Figure 24) and slightly lower than peaks in other years (Figure 33). The zooplankton biomass peak at Prince-5 occurred in June, about a month earlier than the first climatological average peak (Figure24). The annual-average zooplankton biomass anomaly at Prince-5 was negative, and monthly-averaged zooplankton biomass was anomalously low in all months except March and June (Figure 25b).

At Halifax-2, the spring increase in *Calanus finmarchicus* abundance started late and peaked about one month later than normal, in June rather than May (Figure 24). The peak abundance of *C. finmarchicus* was slightly higher than the climatological peak value (Figure 24), but about average compared to peak values in other years (Figure 33). The annual-average *C. finmarchicus* abundance was slightly higher than normal at Halifax-2 in 2008, primarily driven by higher than normal abundances in June and the second half for the year (Figure 25b). In 2008, emergence from dormancy, as indicated by an increase in the proportion of adults compared to fifth copepodite stages in the population, began in January, slightly later than usual, but early copepodite stages began to appear in February, similar to previous years (Figure 26). Early copepodite stages persisted later in summer and fall in 2008 than in most

previous years. Abrupt changes in both the abundance and stage structure of *C. finmarchicus* in March – April suggest an advective influence on the zooplankton at Halifax-2 in the spring of 2008 (Figure 26).

The peak abundance of *C. finmarchicus* at Prince-5 was substantially higher than both the climatological average and peaks in other years, and it occurred in June, about 3 months earlier than the climatological peak (Figure 24) and about 7 weeks earlier than the average peak (Figure 36). The annual average abundance of *C. finmarchicus* was slightly higher than normal at Prince-5, primarily due to higher than average abundance in June and July (Figure 25b). During most of the spring and fall, *C. finmarchicus* abundance was anomalously low. The timing of emergence of dormancy cannot be inferred at Prince-5, due to a gap in sampling in the winter, but early copepodite stages began to appear at the station in March – April (Figure 26). Early copepodite stages were most abundant, relative to later stages, at Prince-5 in May – June, prior to the *C. finmarchicus* peak in June, and again in September – October 2008, when *C. finmarchicus* abundance was low.

Zooplankton abundance at Halifax-2 exhibited an initial peak in April 2008, followed by reduced abundance in May and a higher, annual maximum peak in June, similar to the seasonal change in zooplankton biomass, but much less pronounced (Figure 27). The peak abundance of zooplankton was similar to the average for 1999-2007. Relatively high abundance levels persisted after the spring peak. The zooplankton community at Halifax-2 is dominated by copepods throughout the year, and this pattern continued in 2008. Copepods were least dominant at Halifax-2 in April 2008, similar to previous years. Jellies and appendicularians, particularly *Fritillaria*, and barnacles (included in "Others" in Figure 27) were the dominant non-copepod taxa in the spring. However, the abundance of *Fritillaria* at Halifax-2 in 2008 was relatively low compared to previous years (Figure 28a). The groups "Euphausiidae and Decapoda," represented primarily by euphausiid eggs, and "Cladocera and Bivalvia", represented primarily by the cladoceran *Evadne* spp., made an unusually large contribution to the zooplankton community at Halifax-2 in the late summer and early fall (Figure 27). The abundance of the pteropod *Limacina* was relatively low in 2008, continuing a trend of recent years (Figure 28a). Its abundance has not been high since 2000-2001, but abundance records at Halifax-2 may be strongly influenced by the patchy distribution of this genus.

The seasonal variability pattern in copepod abundance at Halifax-2 in 2008 was similar to the climatological average, although copepod abundance was slightly lower than normal from January to May and from October to November, and higher than normal from June to August (Figure 29). *Calanus finmarchicus* and *Pseudocalanus* spp. contributed to the higher than average abundance of copepods in June through August, although their abundance was relatively low in the first 5 months of the year (Figure 29). Despite low abundance in the spring, peak abundance of *Pseudocalanus* was similar to average in 2008, and higher than the previous 2 years (Figure 28a). The abundance of copepod nauplii also exhibited a moderate abundance peak and later-than-average peak timing (Figure 28a). In 2008, the abundance of the large copepod *Metridia lucens* was lower than average throughout the winter, spring, and summer. *Temora longicornis* was less abundant than usual in the spring, but similar to average in the summer. *Oithona similis* abundance was high year-round, as in past years, but it did not exhibit high wintertime abundance as it does in many years (figures 28a and 29). The large, cold-water copepod *Calanus hyperboreus* was more abundant than average in the late spring (Figure 29), continuing a trend of relatively high peak abundance during recent years (Figure 28a). The abundance of warm water species *Centropages typicus* and *Paracalanus* spp. was lower than average in the summer. In the fall, *Paracalanus* spp. abundance was near normal, but *Centropages typicus* continued to be less abundant than normal (Figure 29). The low

abundance of *C. typicus* follows a trend toward lower abundance since 2001 (Figure 28a), but the abundance of earlier *Centropages* stages has increased during this time (not shown).

Zooplankton abundance at Prince-5 exhibited an unusually high peak in June, similar to the peak in *C. finmarchicus* abundance (Figure 27). In contrast to both zooplankton biomass and *C. finmarchicus* abundance, zooplankton abundance remained relatively high in the summer and fall, similar to past years. The zooplankton community at Prince-5 is less dominated by copepods than the community at Halifax-2 and more variable from year to year. In April – May 2008, the zooplankton community was dominated by barnacles (represented as "Other" in Figure 27). In the summer and fall of 2008, the Prince-5 zooplankton community shifted back to copepod dominance, but the "Jelly and Appendicularian" group, (mainly *Fritillaria* spp.), the "Cladocera and Bivalvia" group (mainly the cladocerans *Evadne* spp. and *Podon* spp.), and the "Euphausiidae and Decapoda" group (mainly euphausiid eggs), were also numerically significant members of the community (Figure 27). The presence of *Fritillaria* spp. at Prince-5 was brief in 2008, as it has been since 2005 (Figure 28b). The peak abundance of euphausiids was relatively high at Prince-5 in 2008 compared to past years (Figure 28b).

The copepod community at Prince-5 is highly variable from year to year, and the seasonal cycle of copepod abundance and community composition at Prince-5 in 2008 was very different from the climatological average cycle (Figure 29). Copepod abundance was lower than normal in the winter and early spring months of 2008 at Prince-5. In June 2008, copepod abundance increased rapidly to levels more than twice the climatological average for June. The dominant copepod in June, by abundance, was *Pseudocalanus*, while *Calanus finmarchicus*, *Oithona similis*, and *Centropages* spp. were also higher than normal (Figure 29). Both *Pseudocalanus* spp. and copepod nauplii exhibited their highest peak abundance of the time series in 2008 (Figure 28b). The abundance of *Oithona similis* increased at Prince-5 earlier in the season in 2008 than in any year since 2001 (Figure 28b). Nearshore copepod species, including *Temora longicornis* and *Eurytemora herdmani*, were lower than average at Prince-5 in 2008 (Figure 29). The abundance of *Acartia clausi*, another nearshore species, was low during the summer of 2008 (figures 28b and 29), but *Acartia* spp., possibly earlier stages of *A. clausi*, were more abundant than usual in the fall. Similarly, *Centropages typicus* abundance was lower than average in 2008, as it has been since 2003 (figures 28b and 29), but *Centropages* spp. abundance was higher than average in the summer and fall. The abundance of the warm-water copepod *Paracalanus* spp. was also lower than normal at Prince-5 in 2008 (Figure 29).

<u>Shelf sections</u>. Springtime zooplankton biomass measured on the AZMP broadscale survey cruises in 2008 was similar to average on both the eastern and western Scotian Shelf (figures 30a and 33). Springtime zooplankton biomass was highest at the western and central Cabot Strait stations, the offshore Louisbourg line stations, and the inshore and offshore Browns Bank line stations. On the Halifax line, which was not completely sampled in spring 2008, zooplankton biomass was highest in the Emerald Basin, while zooplankton biomass at the inshore Halifax line stations, including Halifax-2, was low relative to the rest of the region (Figure 30a). Fall zooplankton biomass in 2008 was similar to the average for past years on the western Scotian Shelf but lower than normal on the eastern Scotian Shelf (figures 30a and 33). The highest fall zooplankton biomass values in 2008 were observed at deep stations in the Cabot Strait, at the shelf break, and on the shelf (Figure 30a).

In 2008, springtime *Calanus finmarchicus* abundance was close to average on both the eastern and western Scotian Shelf (figures 30b and 33). High abundances were observed in offshore water of the Louisbourg section and in Emerald Basin, and extremely high abundances were observed on the offshore end of the Browns Bank line (Figure 30b). Fall *C. finmarchicus* abundance values in 2008 were higher than average on the eastern Scotian Shelf compared to

past years, mainly driven by high abundance on the central part of the Louisbourg line (figures 30b and 33). They were also higher than average on the western Scotian Shelf, primarily due to high abundances observed in the Emerald Basin (figures 30b and 33).

Trawl (groundfish) surveys. In February 2008, the average zooplankton biomass on Georges Bank was the highest yet observed, following a year of very low zooplankton biomass in 2007 (Figure 31). However, this high biomass was driven by high biomass at only 2 stations at the northern edge of the bank, which may have biased the estimate (Figure 31). Zooplankton biomass on the eastern Scotian Shelf in March 2008 was nearly the lowest observed, similar to the 3 previous years. The zooplankton biomass on the Scotian Shelf and eastern Gulf of Maine in July 2008 was the highest observed throughout the time series. *Calanus finmarchicus* abundance on Georges Bank was very high in February 2008, and it is also strongly influenced by a single station. *C. finmarchicus* abundance was similar to the highest values observed on the eastern Scotian Shelf in March 2008. In July 2008, it was higher than previously observed on the Scotian Shelf and in the eastern Gulf of Maine (figures 31 and 33).

Fisheries Oceanography Committee (FOC) scorecard development. Scorecards of key indices, based on normalized, seasonally-adjusted annual anomalies, have been developed in recent years to present physical, chemical, and biological observations in a compact format. Indices of dominant copepod species and groups (*C. finmarchicus, Pseudocalanus spp*., total copepods, and total non-copepods) are included in a standard set that also includes indices representing nutrient availability and primary production in each year at the fixed stations and on transects (Figure 32). A modified version of this approach has been applied to a more detailed set of zooplankton observations in the current year to evaluate interannual variability patterns in specific elements of the zooplankton community, for example in the warm-water shelf community, offshore communities, and *Calanus* species from the Gulf of St. Lawrence (Figure 33). This set of indices presents zooplankton biomass or abundance on the eastern Scotian Shelf (Cabot Strait and Louisbourg sections or groundfish survey stations east of the Halifax section), western Scotian Shelf (Halifax and Browns Bank sections), and western Scotian Shelf and Gulf of Maine (summer groundfish survey stations west of and including the Halifax section) as well as the magnitude and timing of peak biomass or abundance at the Halifax-2 and Prince-5 stations. Indices for zooplankton biomass and *C. finmarchicus* abundance are presented in each season, while indices for other taxa or groups were calculated only for the season or seasons when they are abundant.

While variability among indices and years is high in the standard scorecard, there has been considerable coherence among variables, from nutrients to zooplankton (Figure 32). Overall, 2008 was a year in which nutrients were high, phytoplankton was lower than normal and the bloom was late, and zooplankton abundance, particularly copepods, was high on the Scotian Shelf, reversing a trend toward lower zooplankton abundance (Figure 32). The high levels of zooplankton were less pronounced at Halifax-2, where copepods and non-copepod were lower than average (Figure 32). Variability is even higher in the detailed zooplankton scorecard than in the standard scorecard, since it represents a variety of taxonomic groups that respond differently to environmental variability (Figure 33).

The detailed zooplankton scorecard indicates that zooplankton biomass was very high in the summer of 2008, particularly on the eastern Scotian Shelf, but it was about average in the spring and lower than average in the fall (Figure 33). The abundances of the dominant copepod species *C. finmarchicus* and *Pseudocalanus* spp. were also higher than average overall. *C. finmarchicus* abundance was near average in the spring, but higher than average in the summer and fall. Indices of the peak magnitude of taxa were calculated based on peaks in other years, regardless of their timing, in contrast to evaluation of peak magnitude based on the

climatological seasonal cycle as in Figure 24. This difference leads to discrepancies in the magnitude anomaly between the 2 methods. The indices captured the anomalies in zooplankton biomass and *C. finmarchicus* peak timing observed at Halifax-2 (late) and Prince-5 (early). Zooplankton biomass peaks were lower than average at both fixed stations, and *C. finmarchicus* abundance was higher than average at Prince-5.

The cold-water *Calanus* species *C. hyperboreus* and *C. glacialis* were both lower than average on the shelf in 2008, but their peaks were a bit higher than average at Halifax-2 (Figure 33). The nearshore copepod *Temora longicornis*, which is often abundant in the outflow from the Gulf of Saint Lawrence in the summer and fall, was higher than average on the eastern Scotian Shelf. The numerical dominant copepod *Oithona similis* was more abundant than normal on the eastern Scotian Shelf. The abundances of both warm and cold offshore species were also anomalously low on the Scotian Shelf in 2008. The abundance of warm shelf species was slightly higher than average on the Scotian Shelf, but peak magnitudes were similar to (Prince-5) or lower than (Halifax-2) average at the fixed stations. Appendicularians and *Limacina* spp. were lower than average on the eastern Scotian Shelf but higher than average on the western Scotian Shelf. *Temora longicornis* exhibited the opposite pattern. *Oithona similis* was most abundant than average, and the abundance of *Metridia lucens* was similar to average values.

Continuous Plankton Recorder (CPR). The CPR is the longest data record available on plankton in the Northwest Atlantic (see Figure 4). CPR data analysis lags AZMP reporting by one year; thus, only data up to 2007 are currently available. Abundance trends of major zooplankton taxa have been reported by Head and Pepin (2009).

DISCUSSION

Sufficient data now exists from AZMP (10 years) to document recurring spatial and temporal patterns in optical, chemical, and biological properties of the Maritimes Region and to describe changes (trends) in oceanographic properties with some confidence. Although many of the oceanographic features in the Maritimes Region in 2008 were similar to observations from previous years, a number of differences were noteworthy.

Mixing and optics. The seasonal development of the mixed-layer, stratification, and optical properties of the upper water-column are recurrent features at the Maritimes fixed stations, and are distinctly different for each location. These physical properties are known to influence nutrients distributions and phytoplankton growth cycles. Halifax-2 is notable for its strong seasonally varying hydrographic properties (mixed-layer depths and stratification), whereas Prince-5 is notable for its lack of variability in these properties, due largely to the influence of strong tidal mixing. Prince-5 is also notable for its shallow and invariant euphotic depths, where optical properties are dominated by suspended non-living (detrital) particulates in contrast to Halifax-2, where phytoplankton dominate optical properties. Optical properties appear to be an attribute of both fixed stations that is remarkably invariant or predictable both seasonally and interannually. The most notable features in these physical properties that deviated from the norm in 2008 were the stronger stratification and shallower summer mixed layers at Halifax-2. However, stratification in 2008 at this station was considered normal when assessed against a longer time series of data (back to 1970) (AZMP Bulletin 2009).

Nutrients. Winter maxima in surface nutrients and summer-time reduction in concentrations is a common feature in the Maritimes Region. For the most part, the seasonal cycles of nutrients, vertical structure, and regional variations were similar in 2008 to previous years; there were some differences, however. Winter nutrient inventories were higher than usual at Halifax-2 and

summer inventories lower than usual at both fixed stations, in fact, the lowest summer levels seen since observations began in 1999. At Halifax-2, the timing of maximum spring nutrient draw-down appeared to be later (by approximately 1 month) than usual. During both the spring and fall shelf surveys, nitrate inventories were above normal, but below normal in bottom waters during the July trawl survey, consistent with the observations at the Halifax-2 fixed station.

Winter nitrate inventories in near surface waters (<50 m), when biological activity is at an ebb, should be determined largely by physical processes, principally vertical mixing. Recent analysis of wind patterns on the central Scotian Shelf have shown a strong correlation between late fall wind stress and surface nutrient inventories in winter (B. Petrie, pers. comm.). Slightly above normal wintertime nitrate levels observed at Halifax-2 in 2008, therefore, suggest preceding fall-winter wind conditions were also near normal; however, this has to be verified. The delayed draw-down in nitrate at Halifax-2 would suggest a shift in the phytoplankton growth cycle, which was consistent with the later timing of the bloom in 2008. Why the bloom started later, however, is not clear since physical drivers (e.g. timing of stratification) were normal. Mixing and winter nutrient inventories at Prince-5, in contrast to Halifax-2, are determined largely by tidal processes. Since tidal energy will not generally change significantly from year to year, winter nutrient inventories at that station are relatively invariant.

Summertime nitrate inventories at Halifax-2 were the lowest observed since systematic observations began in 1999. Either greater demand (i.e. more phytoplankton) or less mixing of nitrate into surface waters from depth, or both, would be needed to explain this observation. Since the chlorophyll concentrations were not unusually high in summer 2008 at Halifax-2 (indeed, background levels have been low compared to levels when AZMP started in 1999), reduced vertical mixing and or stronger stratification must have accounted for the low surface nutrients. Shallower mixed layer depths and stronger stratification have been observed, particularly late in the year at this station in recent years; however, deviations of these properties from the norm have been relatively small. An obvious place to look may be trends in summer meteorological conditions – have summer wind conditions changed over the past few years? Summer nutrient inventories have also been declining at Prince-5, but the mechanisms may be fundamentally different than at Halifax-2 as described above. On a broader geographic scale, observations from the shelf section surveys over the past several years suggest that nutrient inventories may be in a general but small decline on the Scotian Shelf from fall surveys. It was not noted, in addition, that bottom water nitrates on the Scotian Shelf in July 2008 were the lower than normal, possibly linked to incursion of low-nutrient Labrador Slope water (Harrison at al. 2008). Indeed, large scale meteorological conditions (e.g. NAO) since about 2000 have been favorable for increased influence of Labrador Slope Water on the Scotian Shelf (B. Petrie, pers. comm.). On the other hand, observations along the Flemish Cap line in the Newfoundland Region indicated enhanced levels of nutrients throughout the year and depths in slope waters compared to levels observed near the adjacent Grand Banks Shelf waters (http://journal.nafo.int/37/maillet/3-maillet.html).

Phytoplankton. Despite the fact that phytoplankton variability (both temporal and spatial) is characteristically high in coastal and shelf waters, the development of pronounced spring/summer (and less conspicuous fall) phytoplankton blooms are evident from observations at the Maritimes fixed stations, seasonal sections, trawl surveys, CPR, and remote-sensing data. Recurring spatial patterns such as the off-shelf bloom that develops in spring, elevated chlorophyll concentrations in summer off southwest Nova Scotia, Georges Bank, the eastern Gulf of Maine/Bay of Fundy, and the elevated concentrations on the eastern Scotian Shelf in fall, are observed almost every year. There were, however, some features of the phytoplankton growth cycle in the Maritimes Region distinctive for 2008, the most prominent of which was the smaller spring bloom on the shelf compared with the record bloom observed in 2007.

Specifically, the magnitude of the bloom at the Halifax-2 fixed station was smaller than usual and spring chlorophyll levels during the shelf survey and from satellite imagery were also lower than normal.

Spring bloom timing (initiation) is thought to be regulated principally by the phytoplankton's light environment that is, in turn, determined by incident irradiance and upper-ocean mixing. At the Halifax-2 fixed station, bloom initiation is driven by the solar cycle, local heating of surface waters, shallowing of the mixed-layer and development of stratification in early spring (March/April). At Prince-5, tidal mixing strongly influences the timing of the bloom which generally starts later in the year (May/June) than at the Halifax-2 (March/April). Bloom magnitude is thought to be regulated largely by nutrient supply and bloom duration regulated by both nutrient supply and secondarily by loss processes such as aggregation and sinking and grazing (principally by zooplankton). Nitrate draw-down at Halifax-2 in 2008 was estimated to be ~250 mmol m^{-2} which would account for ~95% of the peak bloom chlorophyll (267 mg m^{-2}), assuming I mmol of nitrate produces 1 mg chlorophyll. Nitrate draw-down at Prince-5 was ~340 mmol m^{-2} and would account for only ~70% of the bloom (496 mg m^{-2}) at that station in 2008; other sources of nitrogen would be required to make up the difference. The timing of bloom at Prince-5 was similar to the long-term mean in 2008, however, the bloom was delayed and of shorter duration than usual at Halifax-2; bloom duration at Prince-5 was shorter as well. One important factor that could determine bloom duration would be on the biological loss side, i.e. "top-down" control from zooplankton grazing. Zooplankton biomass and, in particular, *Calanus finmarchicus* abundance were well above average during 2008. Interestingly, developmental stages of *C. finmarchicus* peaked later in than usual, perhaps related to the colder than normal seawater conditions during spring (AZMP Bulletin. 2009, Petrie et al. 2009) but the timing of their growth could also be linked to the delayed spring bloom. There is also the possibility that record high zooplankton levels during the spring shelf section surveys contributed to the lower then usual chlorophyll inventories. Low chlorophyll might have, in turn, accounted for the high near surface nutrient inventories observed along the lines, although incursion of high-nutrient water masses could have contributed to the higher than normal nutrients as well (see Harrison et al. 2008). The dynamics of the spring bloom, indeed, is influenced by a complex interaction of physical, chemical and biological processes operating on timescale from days to weeks (Greenan et al. 2004; Smetacek and Cloern 2008). Outside of the bloom period, the general decline background chlorophyll levels at Halifax-2 could be reasonably linked to declining near surface nutrient reserves as evidenced by the lower summer inventories during the last several years. Some progress in answering these important questions on bloom dynamics could be addressed through modelling (scenario-testing).

Recurrent patterns in the seasonal succession of phytoplankton communities at the Maritimes fixed stations also occur. At the Halifax-2 station, a clear transition from diatom-dominated communities in winter/spring to flagellate-dominated communities in summer/fall is evident. At the Prince-5 station, in contrast, diatoms dominate year-round. The only notable change in phytoplankton community structure was observed at Halifax-2 in 2008 where diatoms were unusually low and flagellates unusually high immediately following the spring bloom; on an annual basis, however, community composition was normal.

Zooplankton. Like phytoplankton, zooplankton biomass, abundance, and community composition in the Maritimes Region are characterized by high spatial and temporal variability. Nevertheless, clear seasonal variability patterns are evident at the fixed stations and also in the spring and fall AZMP transect data. At Halifax-2, zooplankton biomass and *Calanus finmarchicus* abundance both peak in April-May on average. Peak abundance and timing are more variable at Prince-5 than at Halifax-2, and zooplankton biomass and *C. finmarchicus* abundance peaks occur later in the season at Prince-5, on average between July and

September. The differences in the zooplankton seasonal cycle at these 2 stations may reflect the differences in the seasonal timing of phytoplankton blooms at these 2 stations.

The most notable trend in the Scotian Shelf zooplankton in 2008 was a late peak in zooplankton biomass and in the abundance *C. finmarchicus*, the biomass dominant copepod on the shelf. Higher-than-average abundance of *C. finmarchicus* persisted into the summer and early fall months. The late development of the zooplankton biomass and *C. finmarchicus* peaks at Halifax-2 were also observed in their seasonal anomalies on the broadscale survey cruises in spring, summer, and fall. The late abundance and biomass peaks may have been related to colder than usual conditions at Halifax-2 in 2008. This interpretation is consistent with higher than normal abundances of the spring/summer species *Pseudocalanus* spp., the cold-water species *C. hyperboreus*, and of euphausiids eggs at Halifax-2. It is also consistent with lower than normal abundances of the warm water species *Centropages typicus* and *Paracalanus* spp. at Halifax-2 in summer 2008. Despite the consistency in annual trends between Halifax-2 and the broader Scotian Shelf observed in zooplankton and *C. finmarchicus*, the cold water *Calanus* species were less abundant than average on the eastern and western Scotian Shelves, in contrast to Halifax-2. Warm-water shelf copepod species were more abundant than normal on the Scotian Shelf in 2008, in contrast to conditions at Halifax-2, and offshore copepod species were less abundant than average on the Scotian Shelf. The difference in abundance anomalies of cold water and warm water species between Halifax-2 and the rest of the Scotian Shelf is consistent with differences between the temperature anomalies between Halifax-2, where the average water temperature was colder than normal, and the Scotian Shelf, where the average water temperature was slightly higher than normal.

Seasonal variability in zooplankton biomass, abundance, and community composition is higher at Prince-5 than at Halifax-2, reflecting the complex dynamics at the Prince-5 site, which is influenced both by the nearshore and outer Bay of Fundy environments, as well as by strong tidal mixing and tidal currents in the area. The zooplankton community at Prince-5 includes both nearshore species, such as the copepods *Acartia clausi*, *Eurytemora herdmani*, *Temora longicornis*, meroplankton such as barnacle and bivalve larvae, and cladocerans, as well as species that are more representative of the central Gulf of Maine such as *C. finmarchicus*, *Oithona similis*, *Pseudocalanus* spp., *Centropages typicus*, *Paracalanus* spp., and euphausiids, which appear in the ring net samples primarily as early stages, from eggs to furcilia. Zooplankton abundance at Prince-5 was lower than normal in the winter of 2008, and the early peak in both zooplankton abundance and biomass was probably due to advection of water from the outer Bay of Fundy rather than local production. The zooplankton community at Prince-5 during the June peak was typical of the Gulf of Maine, rather than nearshore waters of the Bay of Fundy, and was strongly influenced by the abundance of *Pseudocalanus* spp., *C. finmarchicus*, and *Oithona similis*. The very high abundance of copepod nauplii that coincided with the June peak were likely nauplii of *Pseudocalanus* spp. and *C. finmarchicus*. Unlike at Halifax-2, high zooplankton abundance did not persist after the June peak, but the strong influence of offshore waters persisted through the summer when nearshore copepod species were anomalously low in abundance. Nearshore species, including *Temora longicornis* and early stages of *Acartia*, were most prevalent during the second seasonal abundance peak at Prince-5 in October 2008.

The zooplankton biomass distributions observed during AZMP broadscale surveys in spring and fall and during groundfish surveys are highly variable. Generally, biomass is highest in deep waters, including deep basins, channels, and the shelf edge. In addition, biomass has usually been higher on the western Scotian Shelf than on the eastern Scotian Shelf during the summer survey, in contrast to the west-to-east increase in biomass during the spring and fall surveys. These patterns were also observed in 2008, but in addition, unusually high zooplankton

biomass was observed at the inshore station of the Browns Bank line in the spring, and extremely high abundances of *C. finmarchicus* were observed at several stations at the offshore end of the Browns Bank line in the spring of 2008. Zooplankton biomass and *C. finmarchicus* abundance were both unusually high on the eastern Scotian Shelf during the summer groundfish survey cruise.

Ocean acidification is now recognized as a problem that will influence the productivity and community structure of marine organisms, particularly those with calcium carbonate body parts, in the future. One species that may be especially vulnerable to ocean acidification is *Limacina* spp., a pteropod (i.e. pelagic mollusk) species that is a relatively abundant member of the zooplankton community of the Scotian Shelf. This species has a thin calcium carbonate shell that is degraded by low pH seawater. In springtime, *Limacina* spp. is most abundant on the western Scotian Shelf and in the offshore, eastern Scotian Shelf, while in the fall it is most abundant in the outflow of the Gulf of St. Lawrence at the extreme offshore end of the Louisbourg section. In general, *Limacina* spp. was most abundant at the beginning of the AZMP time series, from 1999 to 2001, both at the Halifax-2 station and on the Scotian Shelf (figures 28a and 33). In 2008, its abundance remained low on the eastern Scotian Shelf and close to average on the western Scotian Shelf.

SCORECARD

Another approach being explored for integrating the suite of chemical and biological observations made in AZMP is a scorecard of key indices, based on normalized, seasonally-adjusted annual anomalies. This is similar to the approach adopted for summarizing AZMP's physical variables (AZMP Bulletin, 2008; Figure 2). For the chemical-biological observations, the key variables selected were: (1) near surface (0-50 m) and deep (50-150 m) nitrate inventories, and (2) chlorophyll inventories (0-100 m), the magnitude, timing, and duration of the spring bloom, and zooplankton abundances (*C finmarchicus, Pseudocalanus spp.*, total copepods, total non-copepods) for the fixed stations and seasonal section surveys.

Despite considerable variability among variables and years, there are some clear patterns emerging from the Maritimes Region's scorecard (Figure 32). The first is that for years where there were overall high (or low) scores (e.g. positive: 1999 and to a lesser extent 2003, negative: 2002), there was considerable coherence among variables, from nutrients to zooplankton. Within groups, there is strong coherence among the zooplankton indices over individual years; less so for nutrients and phytoplankton indices. Secondly, the range in scores is generally greater for zooplankton than for nutrients or phytoplankton. Finally, there are about an equal number of years with positive scores as with negative scores (although small) for nutrients and phytoplankton, while there have been more years with negative scores than positive ones for zooplankton, particularly in the most recent years up until 2008. Indeed, there appeared to be a general trend of declining scores for zooplankton over much of the period of AZMP observations with scores consistently negative since 2004. Nutrient, phytoplankton, and zooplankton scores in 2008 showed a number of dramatic reversals compared to 2007 and longer term trends (zooplankton). Nutrient scores were the highest on record in 2008, while phytoplankton scores were down. Zooplankton scores were the highest since 1999, and reversed the 5-year trend of declining conditions. Overall, 2008 would be assessed as an above average year due primary to favorable nutrient and zooplankton conditions; however, it was a relatively poor year for phytoplankton.

ACKNOWLEDGEMENTS

The authors wish to thank the sea-going staff of the Ocean Research and Monitoring Section at the Bedford Institute of Oceanography (BIO) and staff at the St. Andrews Biological Station (SABS), and the officers and crew of the *CCGS Opilio, Hudson, Needler, Templeman, Teleost* and *SAR* vessels for their able assistance in successfully completing the Maritimes/Gulf regions' 2008 field program. Jackie Spry (contractor – Sprytech Biological) provided expert identification and enumeration of zooplankton. AZMP core members provided helpful comments to improve the manuscript.

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Table 1. Atlantic Zonal Monitoring Program (AZMP) AZMP Sampling missions in the Maritimes/Gulf regions, 2008. SGSL = southern Gulf of St. Lawrence.

Group	Location	Mission ID	Dates	# Hydro Stns	# Net Stns
Trawl Surveys	Georges Bank & West Shelf	TEM2008-775	Mar 04 - 21	62	20
	Eastern Shelf	TEL2008-805	Mar 19 - 28	66	13
	Scotian Shelf	TEM2008-830	Jul 06 – Aug 01	167	33
	SGSL	TEL2008-815	Aug 28 - Sep 22	195	16
Seasonal Sections	Scotian Shelf	HUD2008-004	Apr 11 – Apr 28	65	53
	Scotian Shelf	HUD2008-009	Jun 01 – 03	11	4
	Scotian Shelf	HUD2008-037	Sep 28– Oct 20	65	41
Fixed Stations	Shediac Valley	BCD2008-668	May 6 – Dec 03	8	8
	Halifax-2	BCD2008-666	Jan 04 – Dec 11	18	18
	Prince-5	BCD2008-669	Jan 14 – Dec 15	12	12
			Total:	654	203

Table 2. Chemical and biological properties of the 1999-2008 spring and fall Scotian Shelf sections. Statistics: Section means (average of all stations).

	Nitrate 0-50 m (mmol m^{-2})		CHL 0-100 m (mg m^{-2})		Zoopl Biomass (g wet wt m^{-2})		*C. finmarchicus* (Indx10^{3} m^{-2})	
Year	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Cabot								
1999	133	140	423	47	23	40	17	38
2000	92	31	549	38	29	33	5.3	29
2001	31	120	137	35	90	86	6.2	28
2002	-	238	-	69	-	-	-	-
2003	-	76	-	38	-	85	-	39
2004	98	81	326	26	79	271	8.3	34
2005	137	84	157	34	67	47	18	22
2006	48	144	260	11	55	87	9.8	30
2007	140	110	291	37	37	64	11	41
2008	140	122	168	41	60	52	12	24
Louisbourg								
1999	99	91	177	53	17	8.8	68	10
2000	94	24	378	38	13	8.4	23	3.0
2001	29	72	152	39	95	34	13	13
2002	-	37	-	41	-	43	-	27
2003	81	71	710	39	90	16	15	6.7
2004	48	77	405	29	47	30	10	23
2005	48	79	397	30	56	17	21	9.8
2006	62	94	151	28	42	16	29	8.4
2007	72	92	597	24	29	12	12	15
2008	115	41	195	39	45	31	14	38
Halifax								
1999	144	93	53	36	17	10	65	8.0
2000	90	22	165	45	18	14	47	8.9
2001	29	99	126	31	90	25	52	8.2
2002	-	38	-	25	-	21	-	7.0
2003	51	53	313	35	80	29	54	8.9
2004	44	56	77	34	53	71	33	8.8
2005	63	60	354	30	41	28	56	11
2006	80	64	39	6.7	50	30	27	15
2007	52	63	720	35	29	25	19	10
2008	119	100	267	44	41	37	25	15
Browns								
1999	124	143	58	83	12	28	75	2.8
2000	239	26	154	45	-	17	25	5.4
2001	30	175	116	59	89	26	59	16
2002	-	109	-	36	-	34	-	15
2003	157	145	545	58	74	42	49	31
2004	133	118	219	26	34	26	28	4.5
2005	187	98	165	37	28	17	26	5.4
2006	152	130	44	51	34	26	65	12
2007	53	115	680	29	40	14	15	8.3
2008	195	174	102	59	61	29	81	12

Table 3. Chemical and biological properties of the 1999-2008 summer Scotian Shelf ecosystem trawl (groundfish) survey. Statistics: means, (ranges), #obs. Numbers in brackets in oxygen column represent percent area of shelf covered by bottom waters with <60% oxygen saturation.

Year	Chlorophyll ($mg\ m^{-3}$) Surface (5 m)	Nitrate ($mmol\ m^{-3}$) Bottom	Oxygen (% Saturation) Bottom	Zoopl Biomass ($g\ wet\ wt\ m^{-2}$)	*C. finmarchicus* ($Ind\ m^{-2}$)
1999	**0.93** (0.10-7.07) 137	**13.22** (2.12-24.06) 163	**77 [7.3]** (41.9-106.7) 197	**45.9** (0.2-228.2) 32	**20,872** (91-143,060) 33
2000	**0.67** (0.11-6.17) 220	**12.87** (3.27-22.97) 178	**87 [12.4]** (43-121) 203	**34.0** (2.7-158.6) 38	**37,625** (2.7-238.1) 38
2001	**0.78** (0.03-4.08) 206	**11.75** (1.72-21.76) 155	**82 [9.9]** (40-107) 206	**34.4** (1.2-144.8) 38	**32,598** (43-185,472) 37
2002	**0.51** (0.08-4.17) 303	**10.96** (0.32-22.66) 215	**74 [6.2]** (28-109) 215	**27.0** (1.0-120.1) 38	**25,906** (9-171,131) 38
2003	**0.72** (0.03-6.65) 214	**11.01** (0.14-23.27) 213	**78 [9.7]** (34-109) 217	**34.9** (1.07-252.5) 34	**33,224** (1154-233,326) 34
2004	**0.56** (0.12-5.25) 185	**10.35** (0.14-24.28) 193	**81 [12.8]** (36-110) 191	**36.9** (2.51-182.2) 38	**37,036** (151-219,398) 38
2005	**0.56** (0.001-3.83) 192	**10.98** (0.44-23.10) 191	**78 [8.2]** (43-103) 191	**19.5** (0.32-46.6) 34	**19,181** (24-143,063) 34
2006	**0.69** (0.05-4.74) 201	**11.48** (0.01-22.82) 207	**77 [5.2]** (41.62-110.58) 207	**31.44** (1.81-135.76) 41	**42,837** (431-109560) 41
2007	**0.68** (0.18-3.19) 163	**9.56** (0.12-19.96) 161	**77 [10.9]** (43.32-113.55) 163	**26.9** (0.69-115.88) 34	**29,703** (830-138987) 35
2008	**0.64** (.06-4.43) 165	**10.47** (.719-22.79) 167	**79 [7.8]** (41.2-112.4) 165	**60.9** (3.11-242.2) 33	**65,037** (288-229982) 33

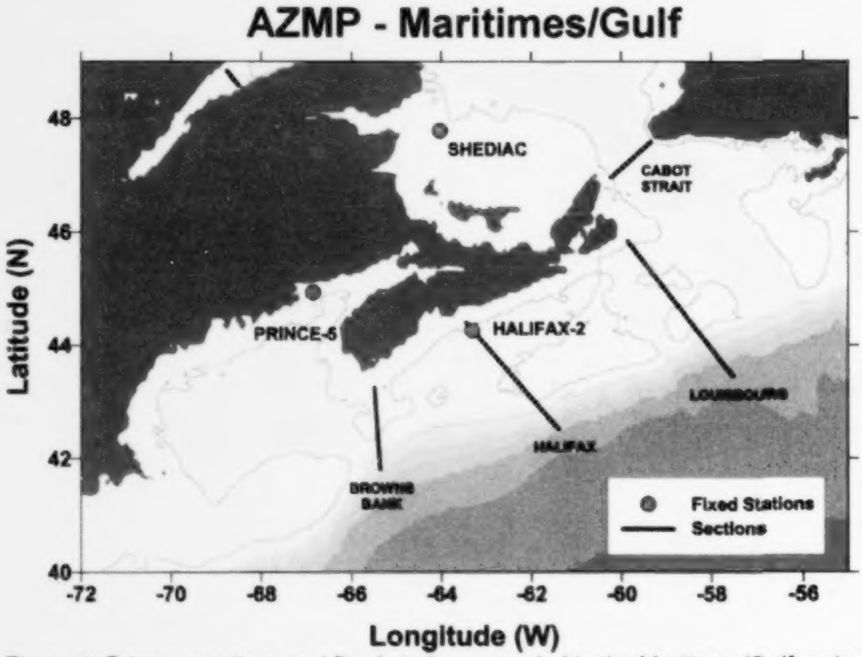


Figure 1. Primary sections and fixed stations sampled in the Maritimes/Gulf regions.

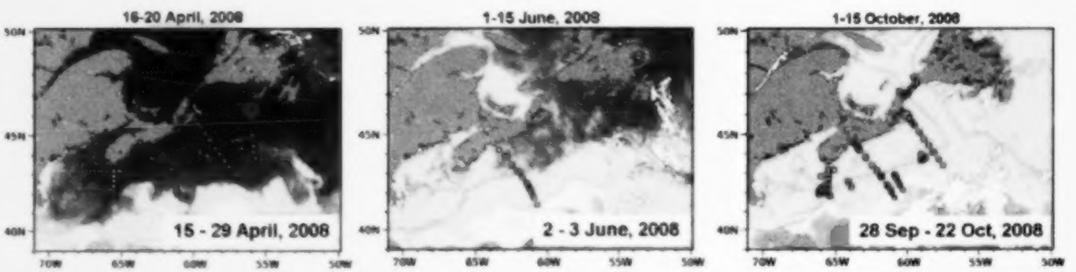


Figure 2. Stations sampled during the 2008 spring, summer and fall section surveys. Station locations superimposed on twice monthly sea surface temperature (SST) composite images.

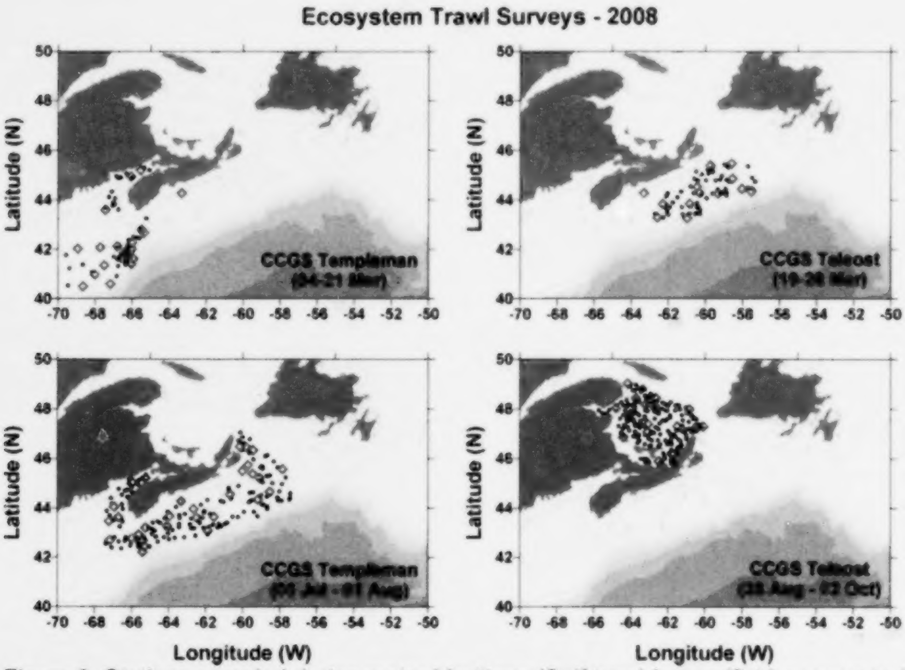


Figure 3. Stations sampled during major Maritimes/Gulf trawl (groundfish) surveys in 2008. Black symbols are hydrographic stations; red symbols are stations where vertical nets hauls were taken in addition to hydrographic measurements.

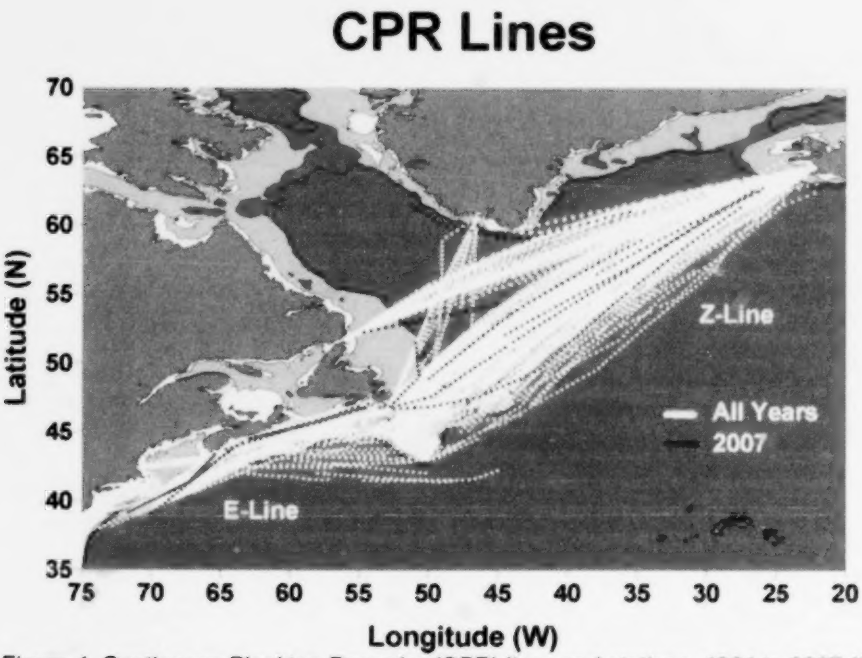


Figure 4. Continuous Plankton Recorder (CPR) lines and stations, 1961 to 2007 (2007 highlighted).

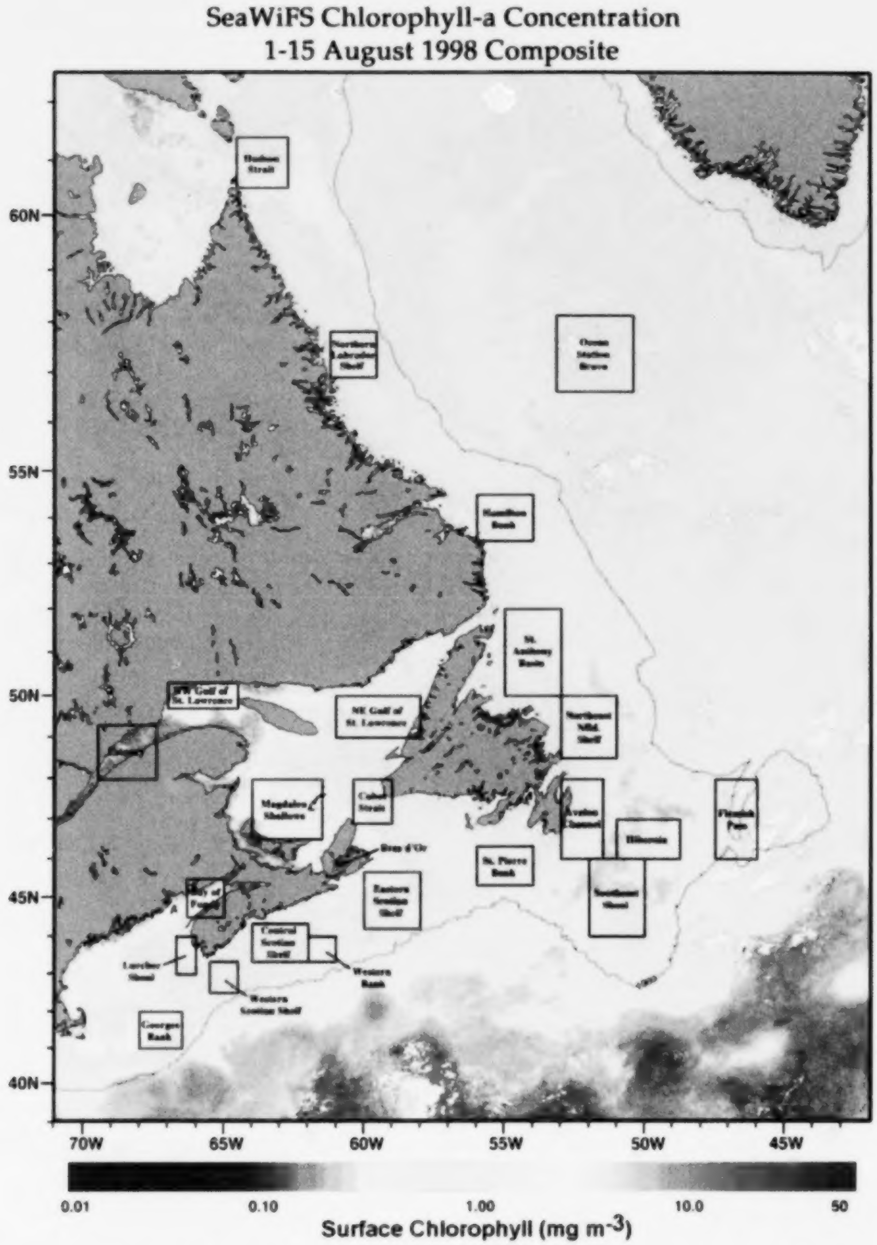


Figure 5. Statistical sub-regions in the Northwest Atlantic identified for spatial/temporal analysis of SeaWiFS/MODIS ocean colour data.

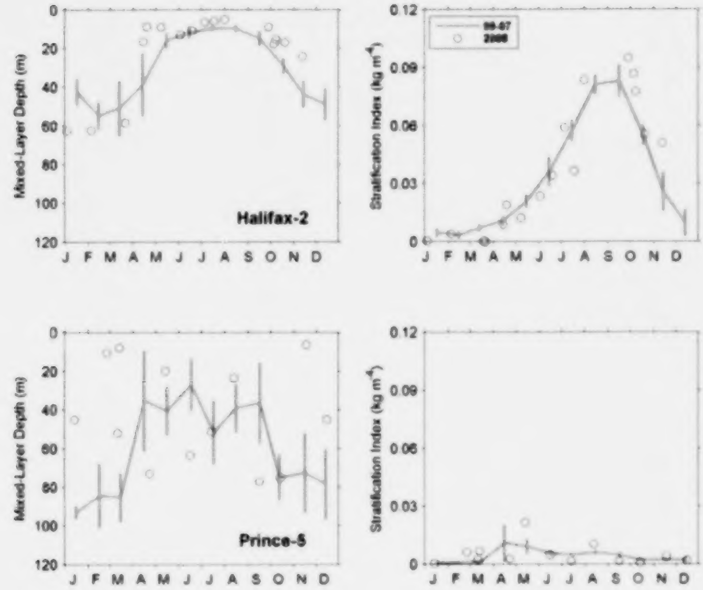


Figure 6. Mixing properties (mixed-layer depth, stratification index) at the Maritimes fixed stations. Year 2008 data (circles) compared with mean conditions from 1999-2007 (solid line). Vertical lines are 95% confidence limits.

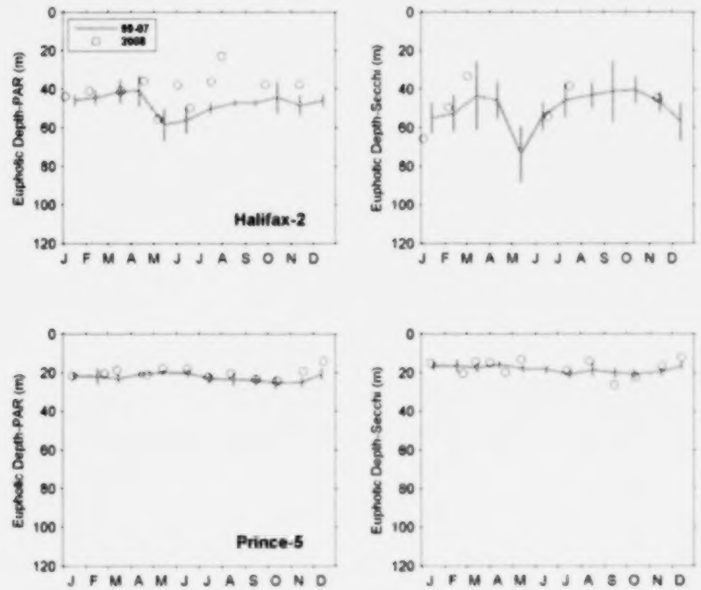


Figure 7. Optical properties (euphotic depth from PAR irradiance meter and Secchi disc) at the Maritimes fixed stations. Year 2008 data (circles) compared with mean conditions from 1999-2007 (solid line). Vertical lines are 95% confidence limits.

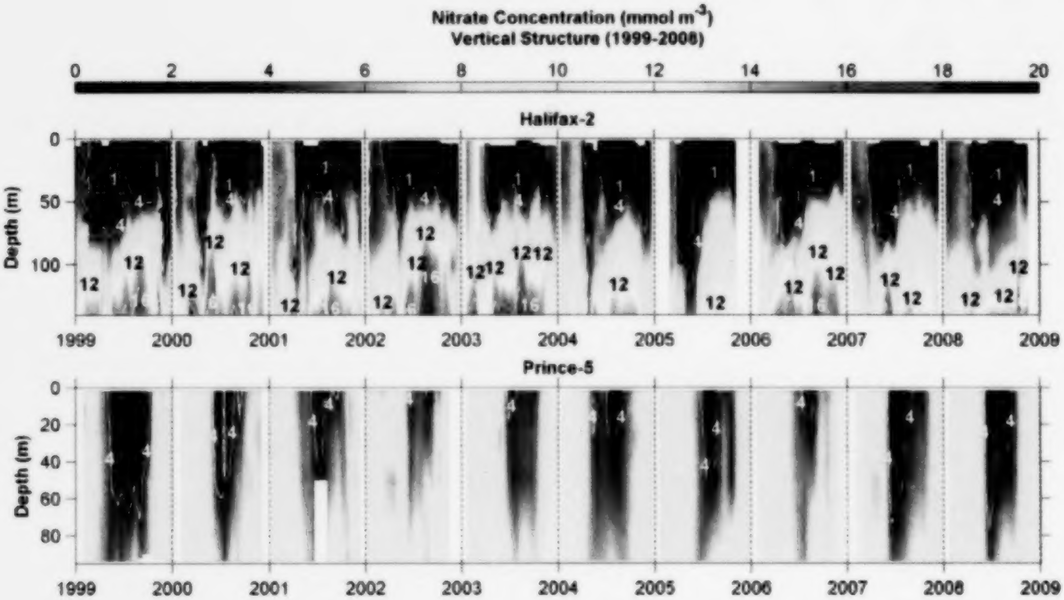


Figure 8. Time series of vertical nitrate structure at the Maritimes fixed stations, 1999-2008.

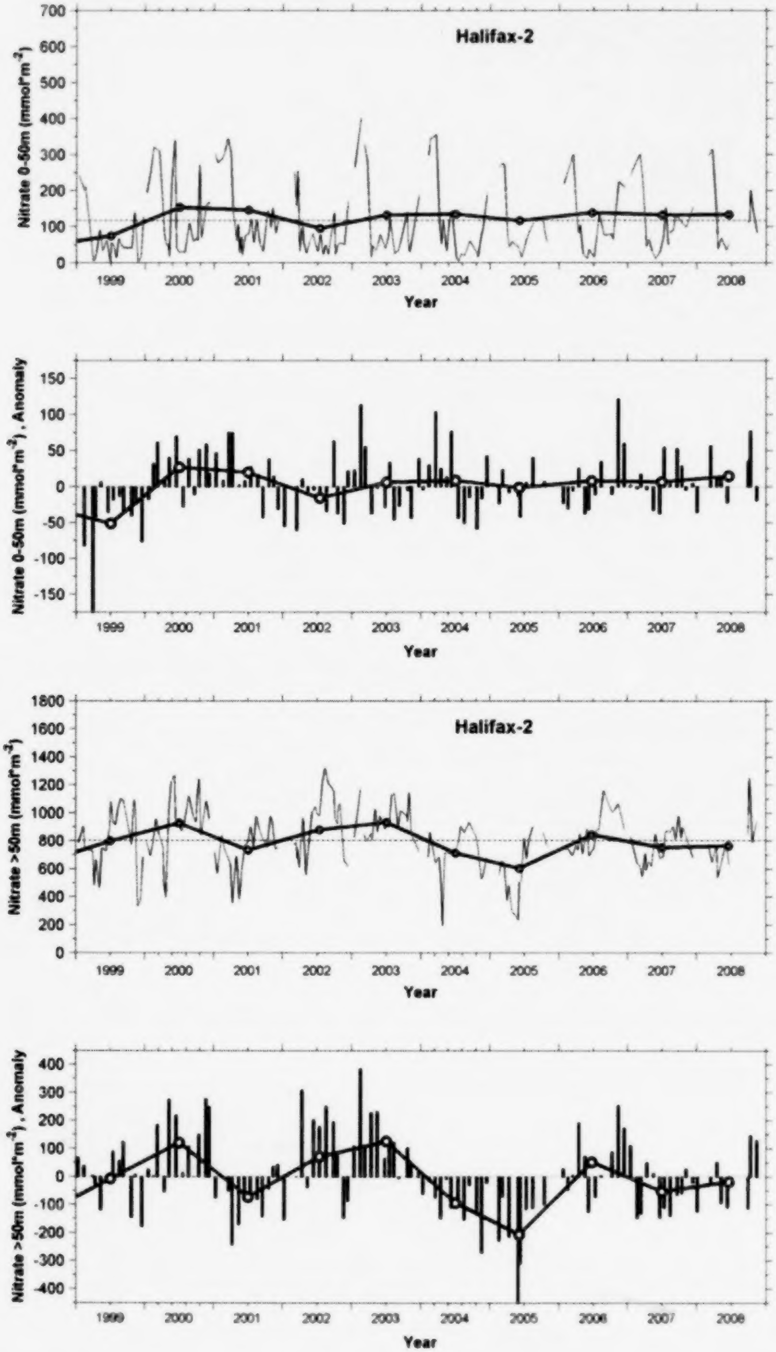


Figure 9a. Nitrate inventories at the Halifax-2 fixed station, 1999-2008. Top 2 panels: surface (0-50 m) time series with annual averages (solid line); monthly (vertical bars) and annual (solid line) anomalies. Bottom 2 panels: deep (>50 m) time series with annual averages (solid line); monthly (vertical bars) and annual (solid line) anomalies. Dashed lines are overall mean levels.

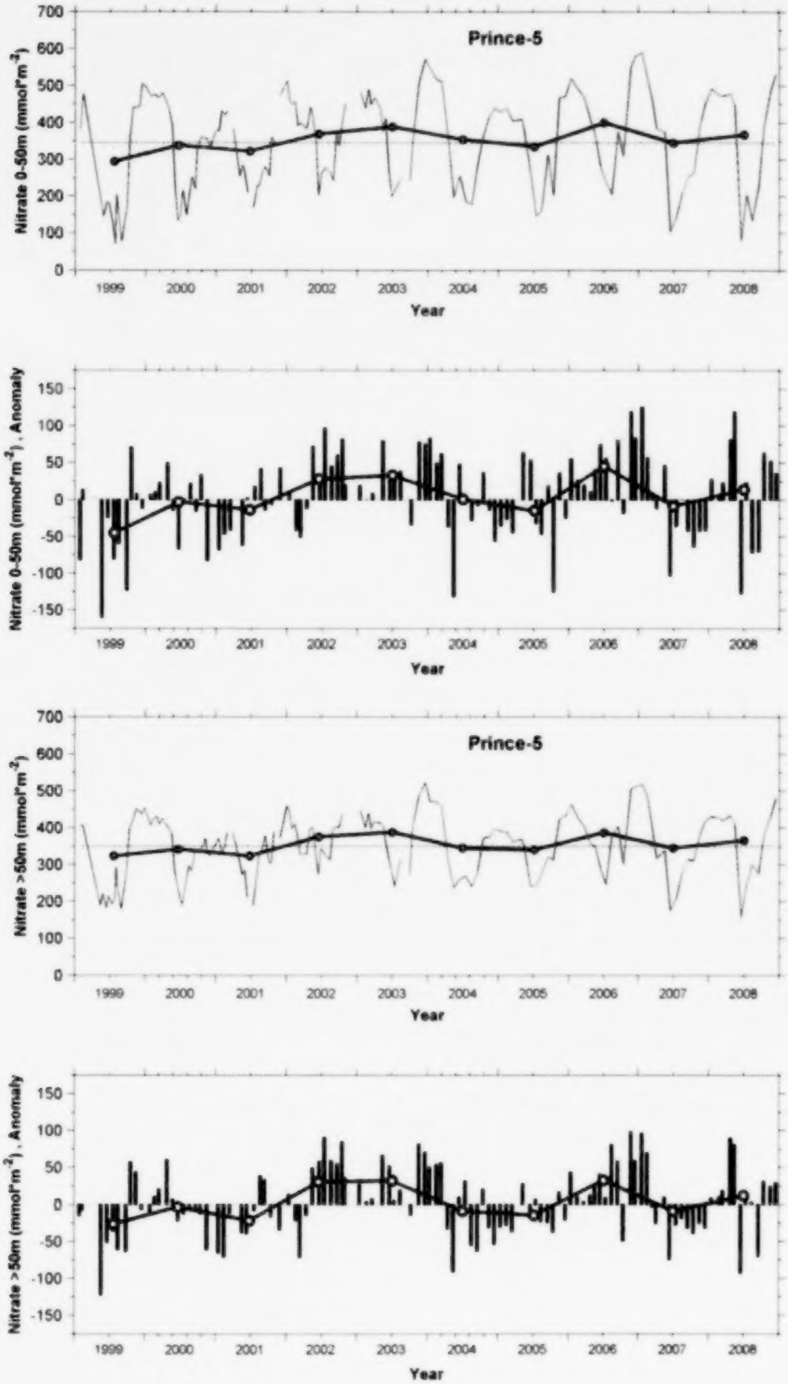
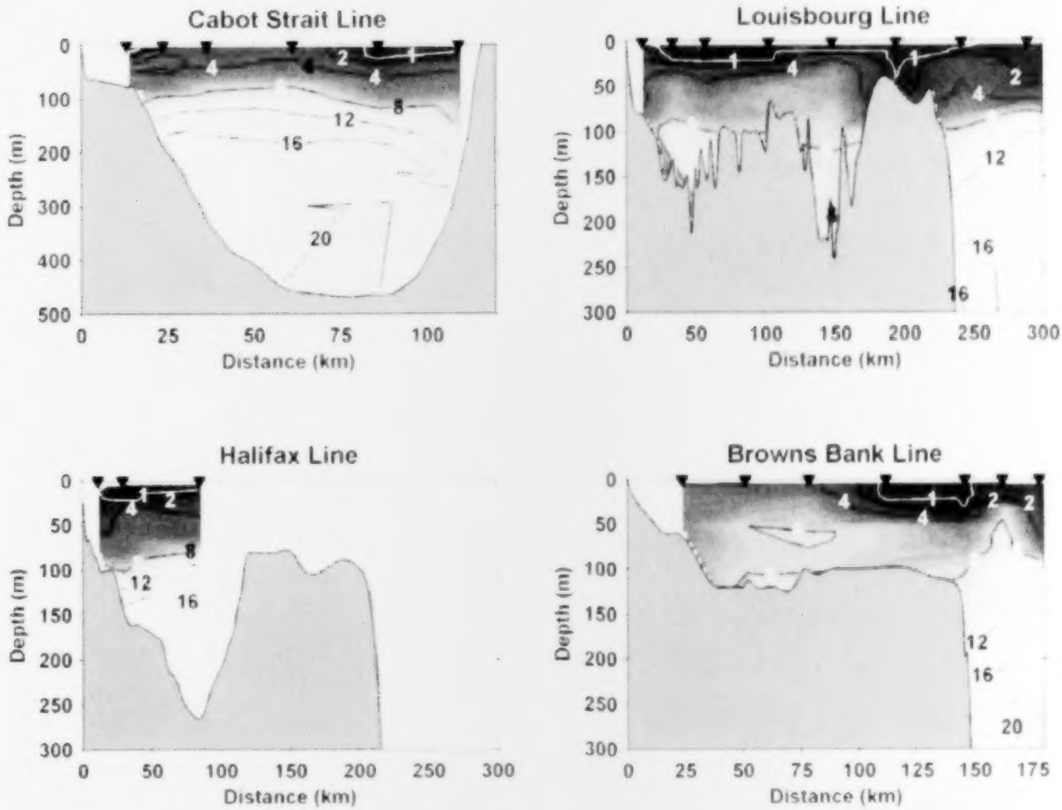
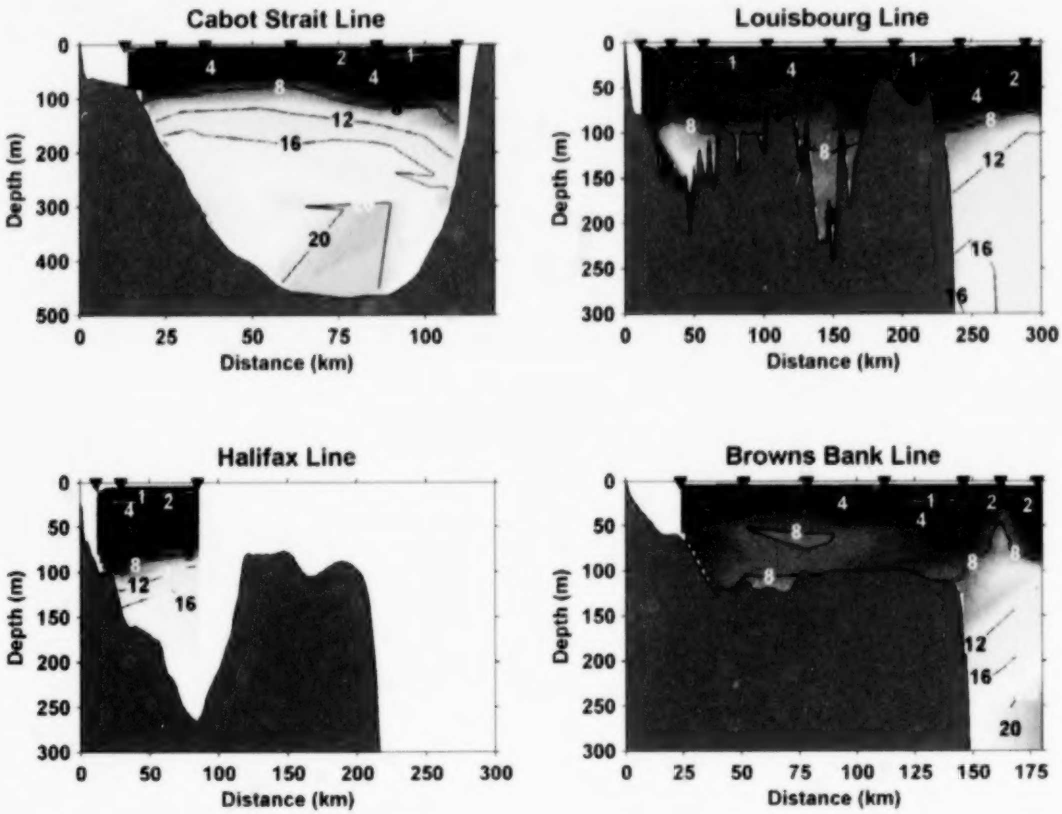


Figure 9b. Nitrate inventories at the Prince-5 fixed station, 1999-2008. Top 2 panels: surface (0-50 m) time series with annual averages (solid line); monthly (vertical bars) and annual (solid line) anomalies. Bottom 2 panels: deep (>50 m) time series with annual averages (solid line); monthly (vertical bars) and annual (solid line) anomalies. Dashed lines are overall mean levels.



AZMP Sections		
Nitrate (mmole m^{-3})		
Cruise HUD2008004	(Spring 2008)	
Cabot Strait Line	:	Apr 24
Louisbourg Line	:	Apr 22-27
Halifax Line(3 stns)	:	Apr 15
Browns Bank Line	:	Apr 17-18

Figure 10. Vertical nitrate structure along the Scotian Shelf sections during the spring survey in 2008.



AZMP Sections
Nitrate (mmole m^{-3})

Cruise HUD2008004		**(Spring 2008)**
Cabot Strait Line	:	**Apr 24**
Louisbourg Line	:	**Apr 22-27**
Halifax Line(3 stns)	:	**Apr 15**
Browns Bank Line	:	**Apr 17-18**

Figure 10. Vertical nitrate structure along the Scotian Shelf sections during the spring survey in 2008.

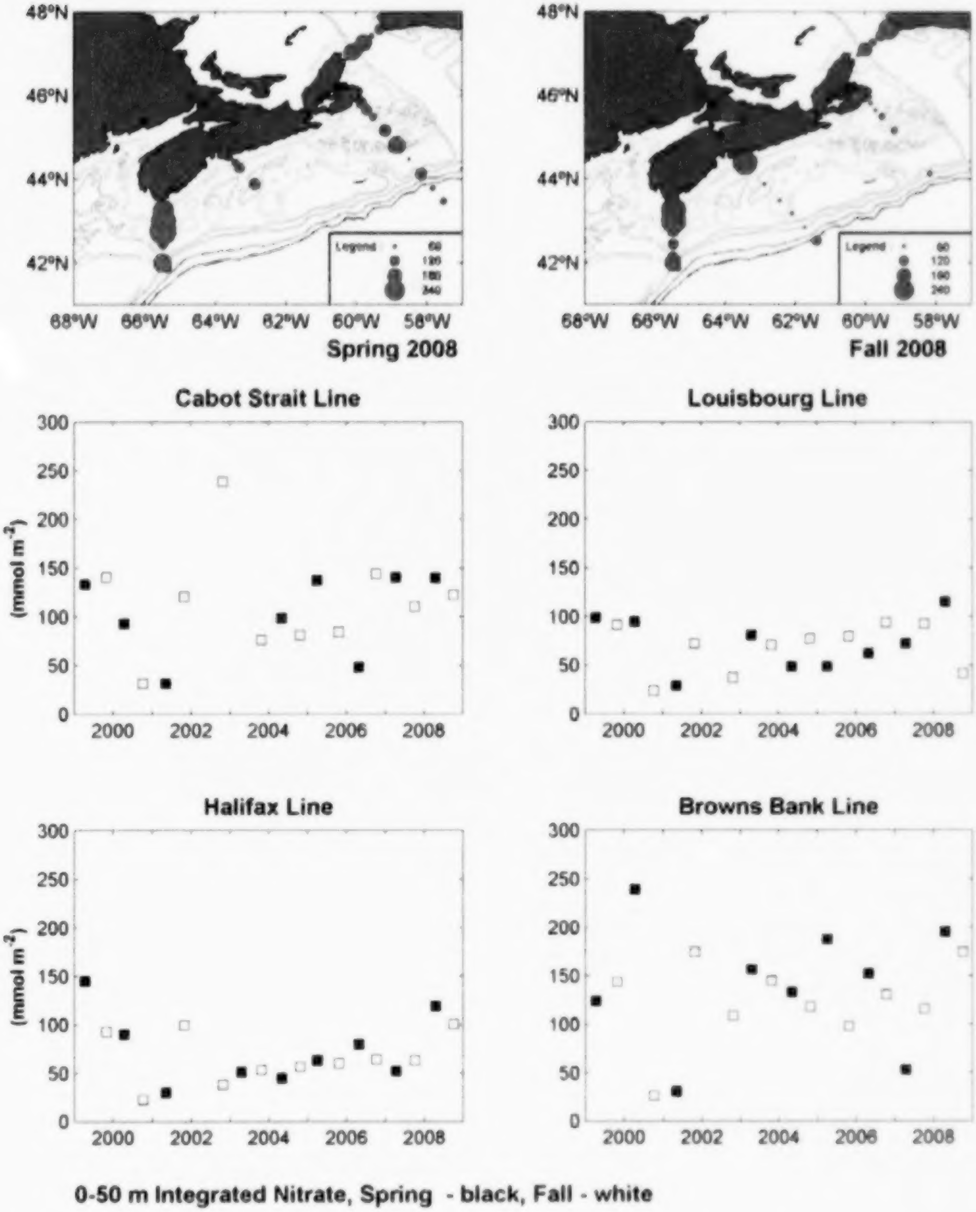


Figure 11a. Time series of line-averaged inventories of nitrate in the upper water column (0-50 m) for the spring and fall Scotian Shelf sections, 1999-2008.

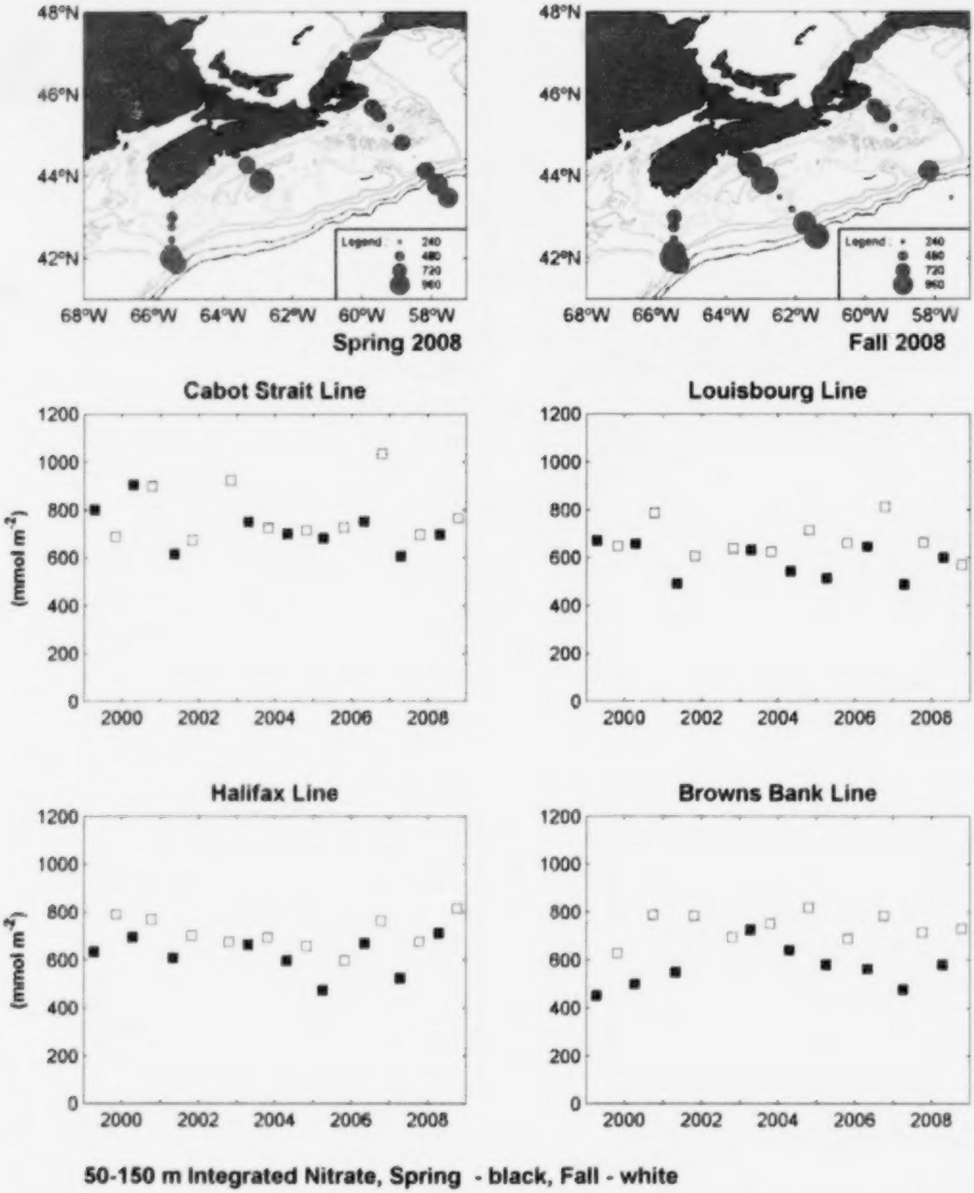


Figure 11b. Time series of line-averaged inventories of nitrate in deep waters (>50 m) for the spring and fall Scotian Shelf sections, 1999-2008.

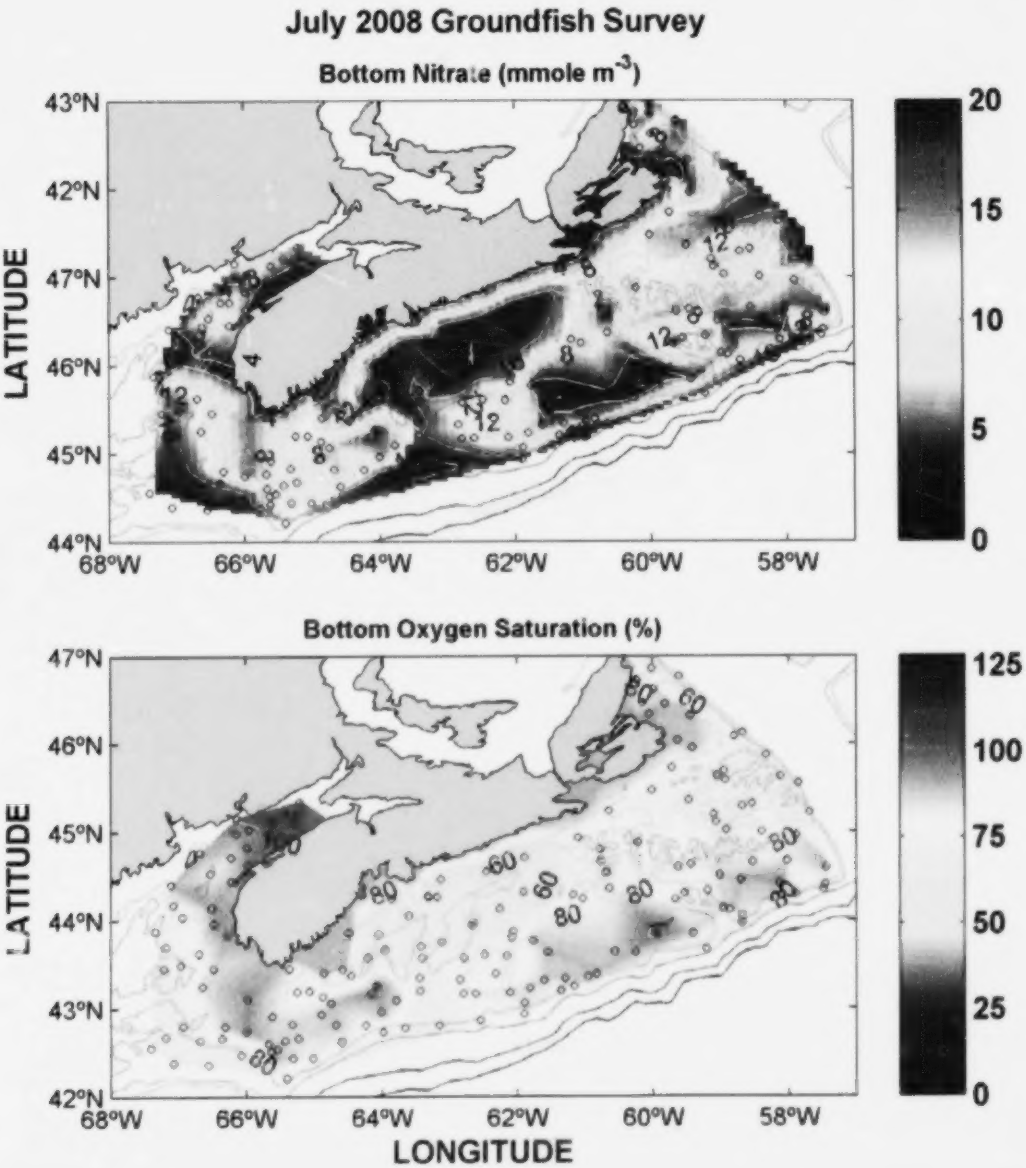


Figure 12. Bottom nitrate concentrations (upper panel) and oxygen saturation (lower panel) on the Scotian Shelf during the annual July trawl (groundfish) survey in 2008.

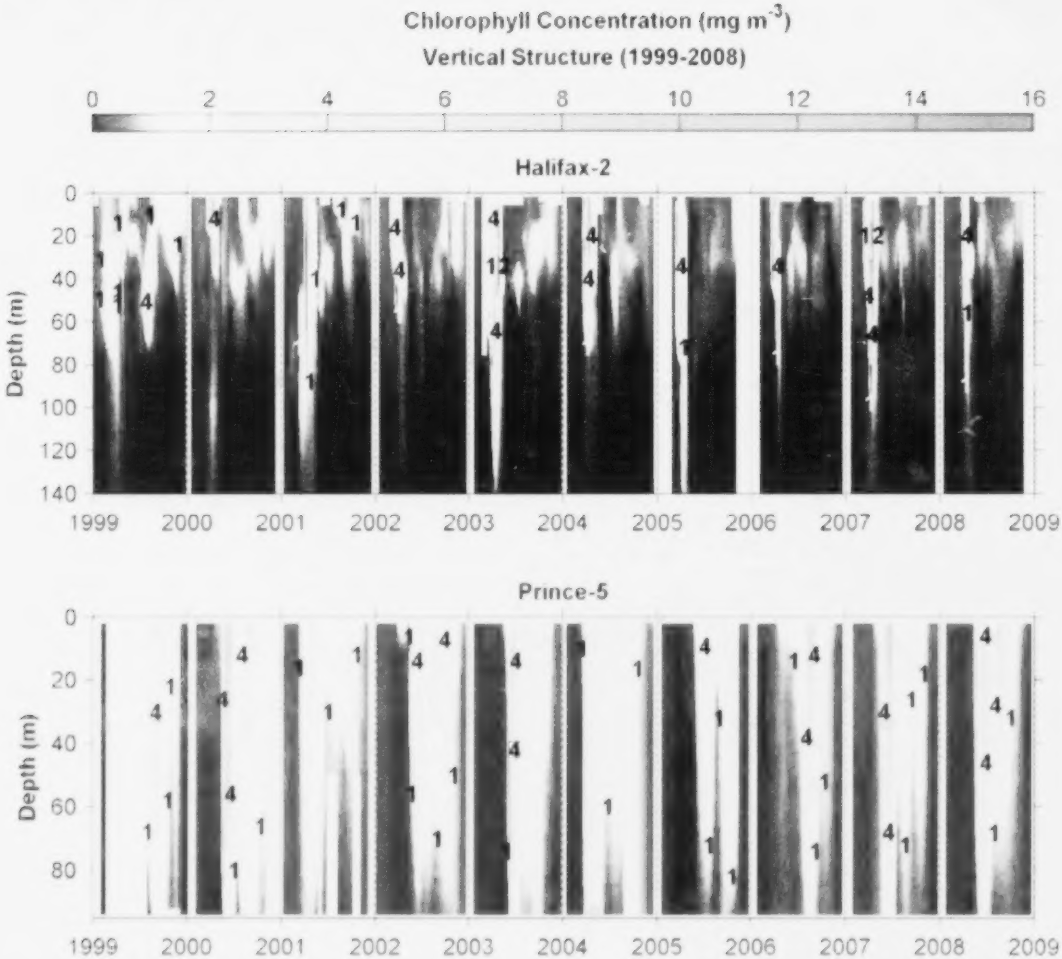


Figure 13. Time series of vertical chlorophyll structure at the Maritimes fixed stations, 1999-2008.

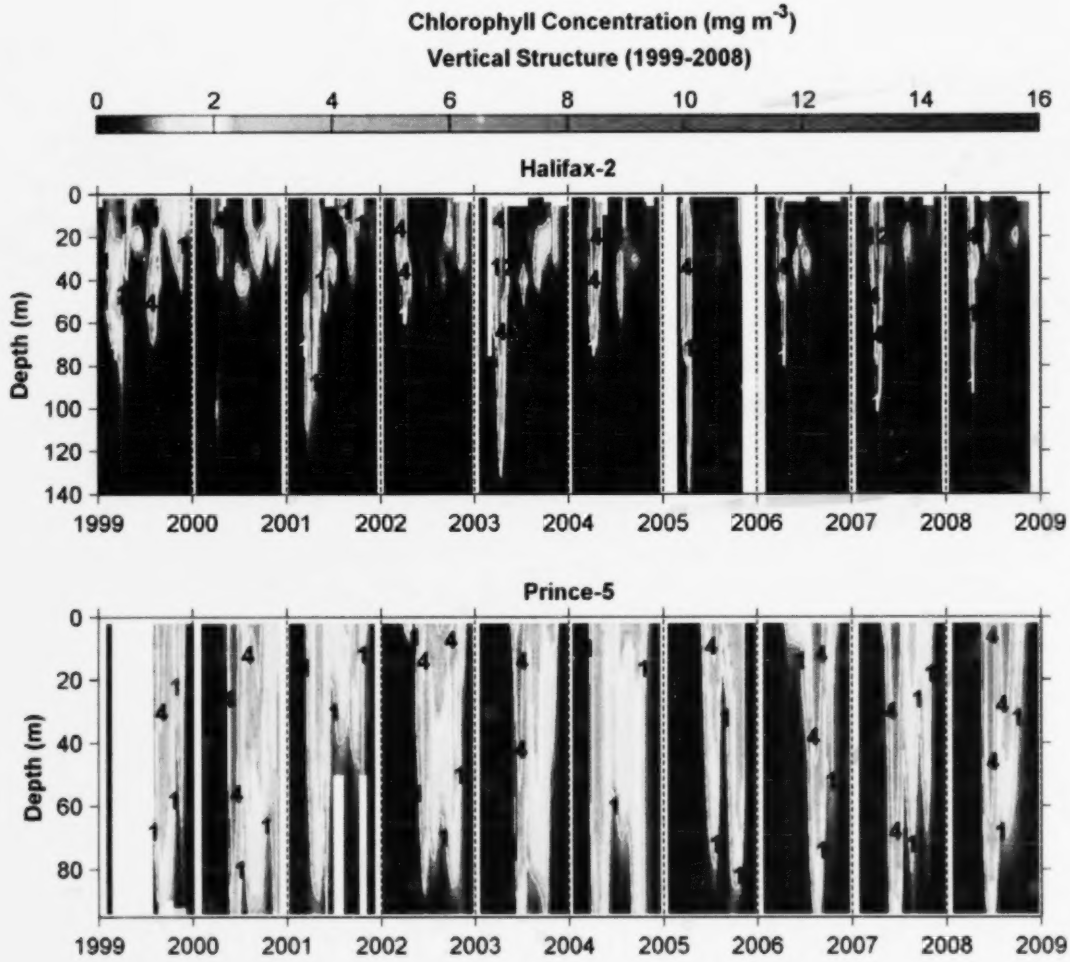


Figure 13. Time series of vertical chlorophyll structure at the Maritimes fixed stations, 1999-2008.

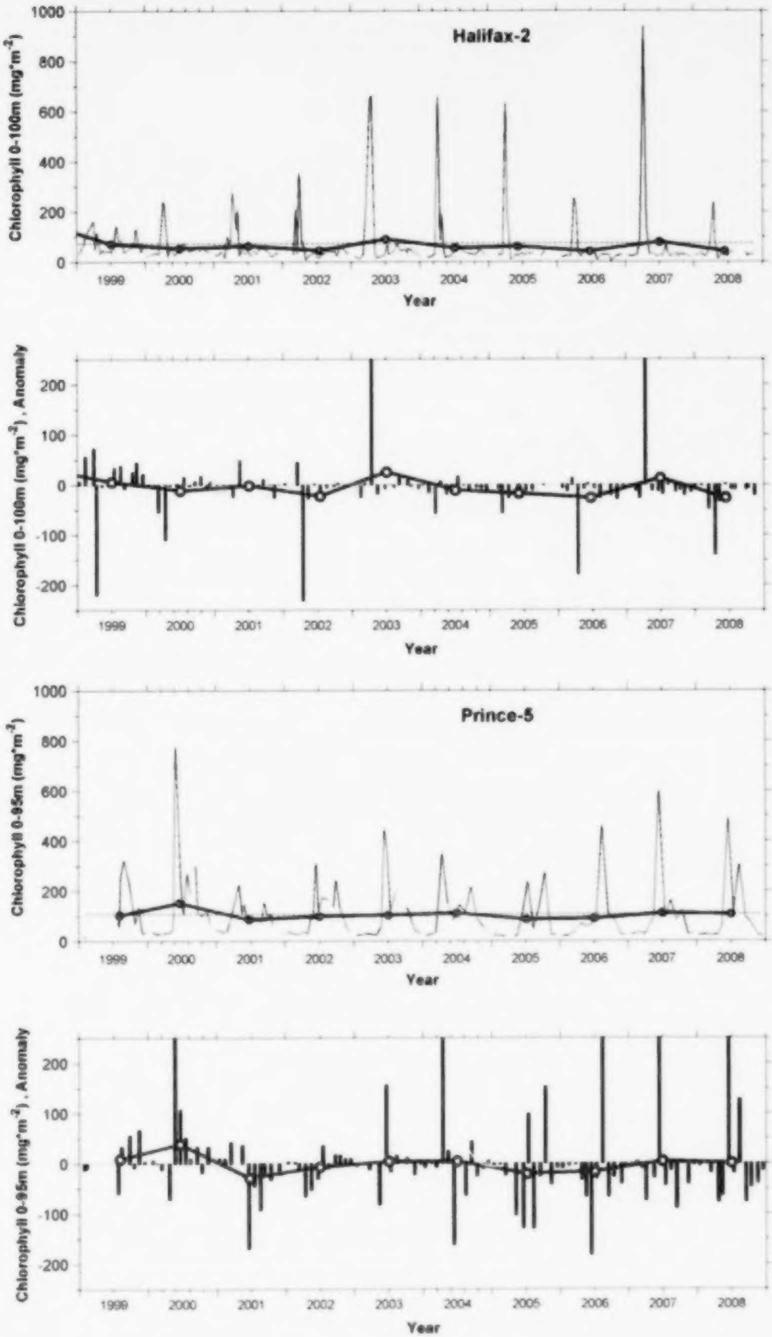


Figure 14. Chlorophyll inventories (0-100 m) at the Maritimes fixed station, 1999-2008. Top 2 panels: Halifax-2 time series with annual averages (solid line); monthly (vertical bars) and annual (solid line) anomalies. Bottom 2 panels: Prince-5 time series with annual averages (solid line); monthly (vertical bars) and annual (solid line) anomalies. Dashed lines are overall mean levels.

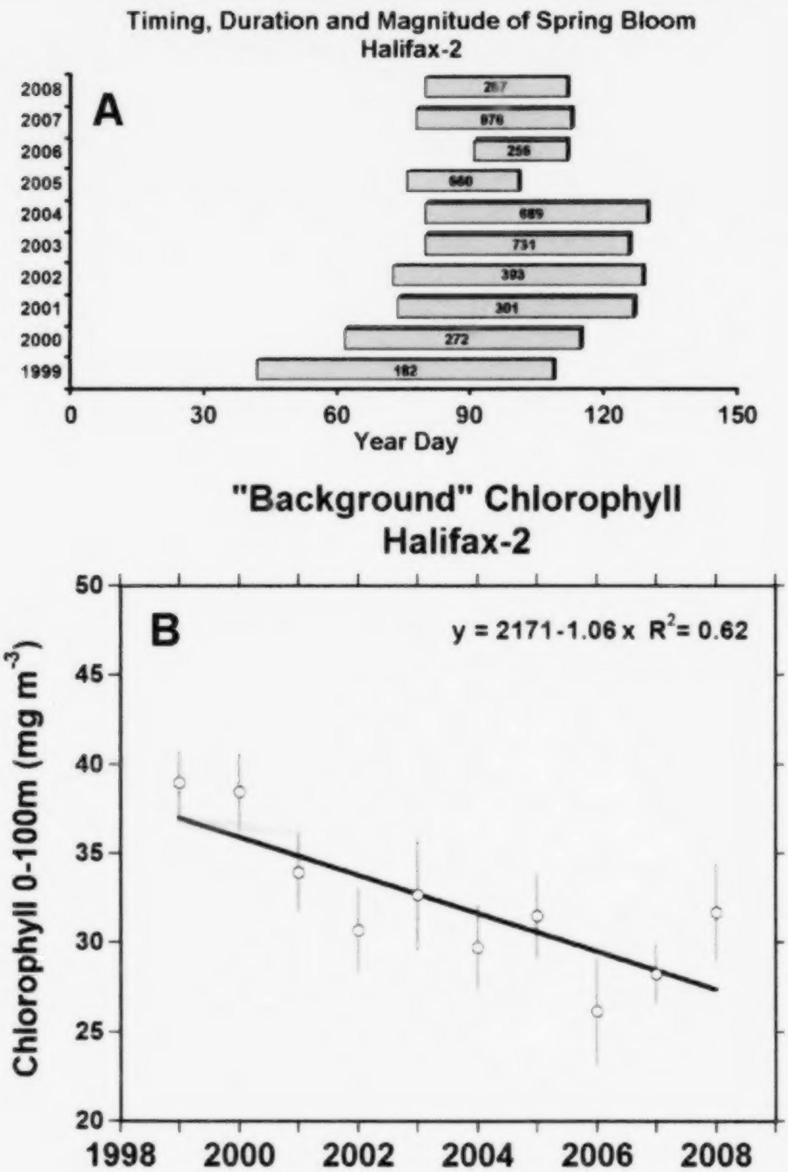


Figure 15. Dynamics of the spring phytoplankton bloom at the Halifax-2 fixed station, 1999-2008: (A) timing, duration (based on 40 mg CHL m^{-2} threshold for determining start and end of the bloom), and magnitude (numbers inside horizontal bars); (B) "background" chlorophyll levels, i.e. outside of spring bloom periods (annual averages +/- SE, line = least squares linear regression).

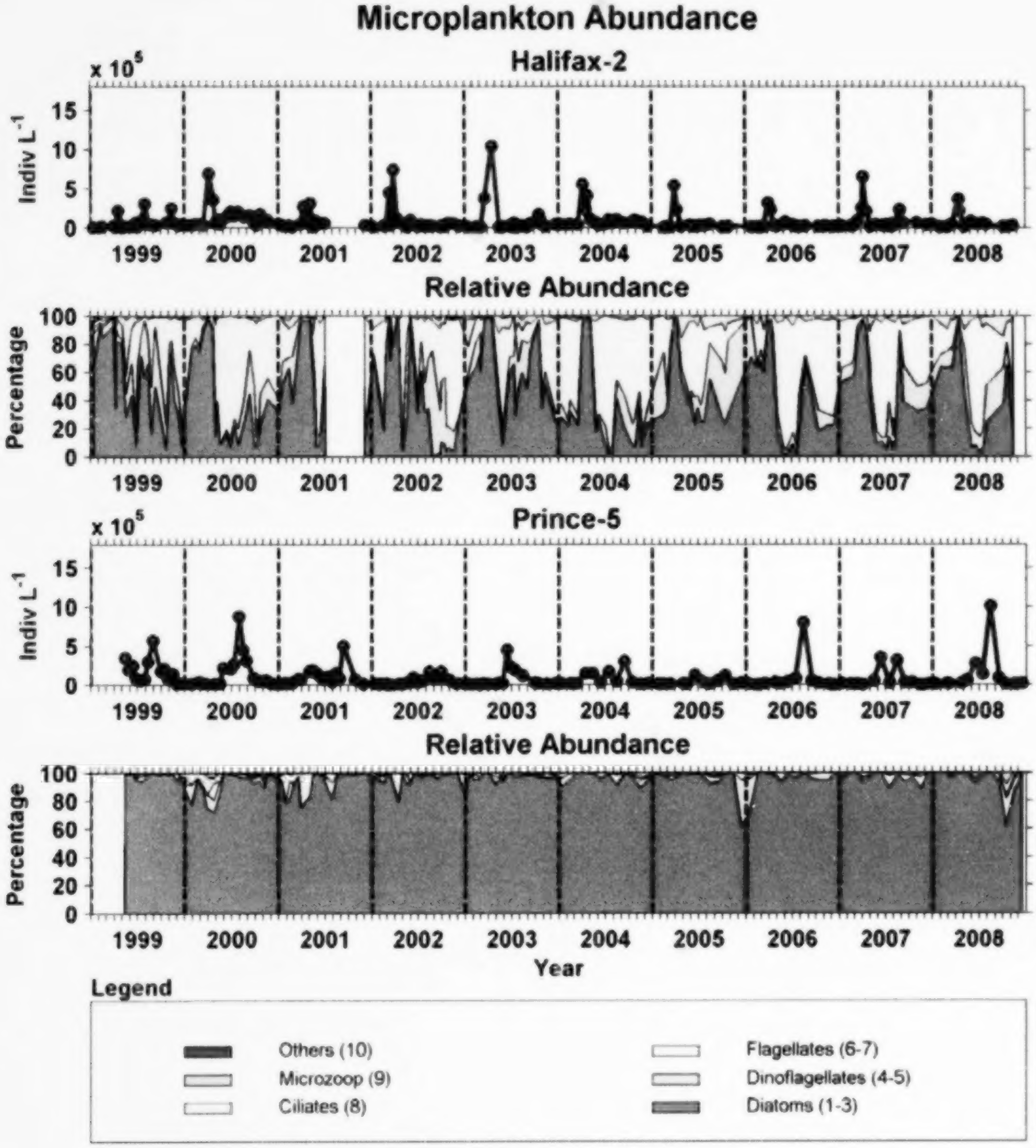
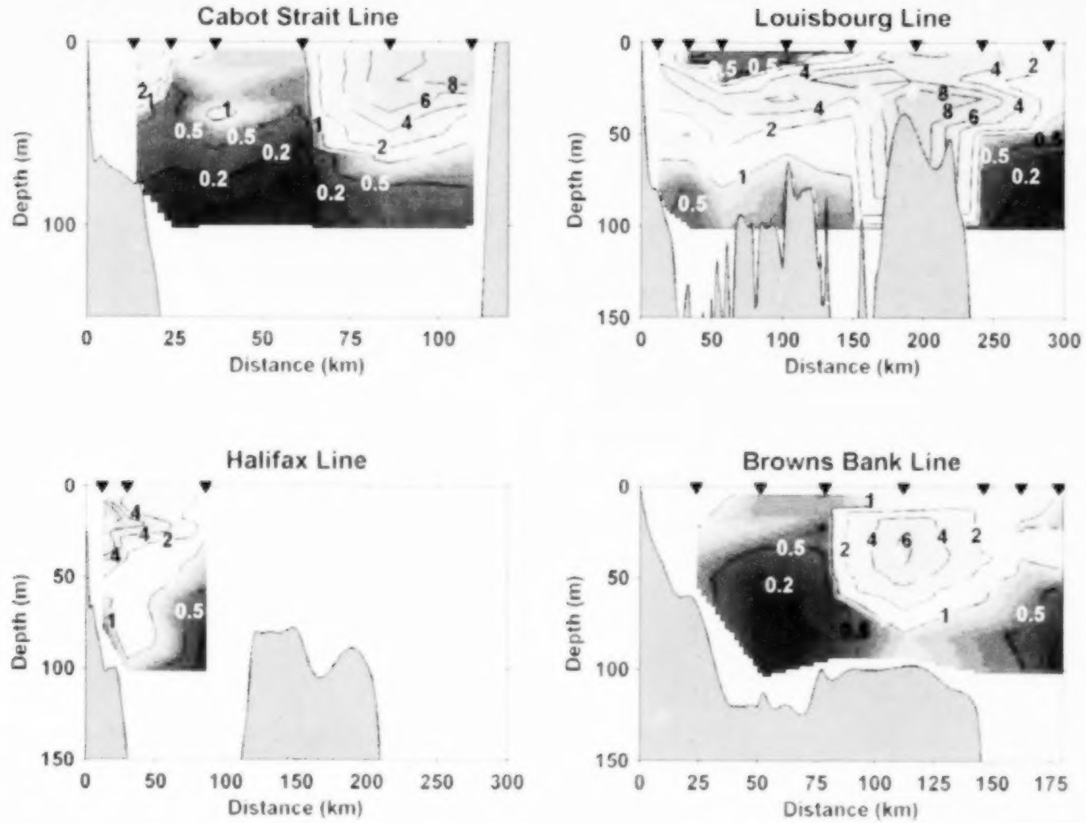


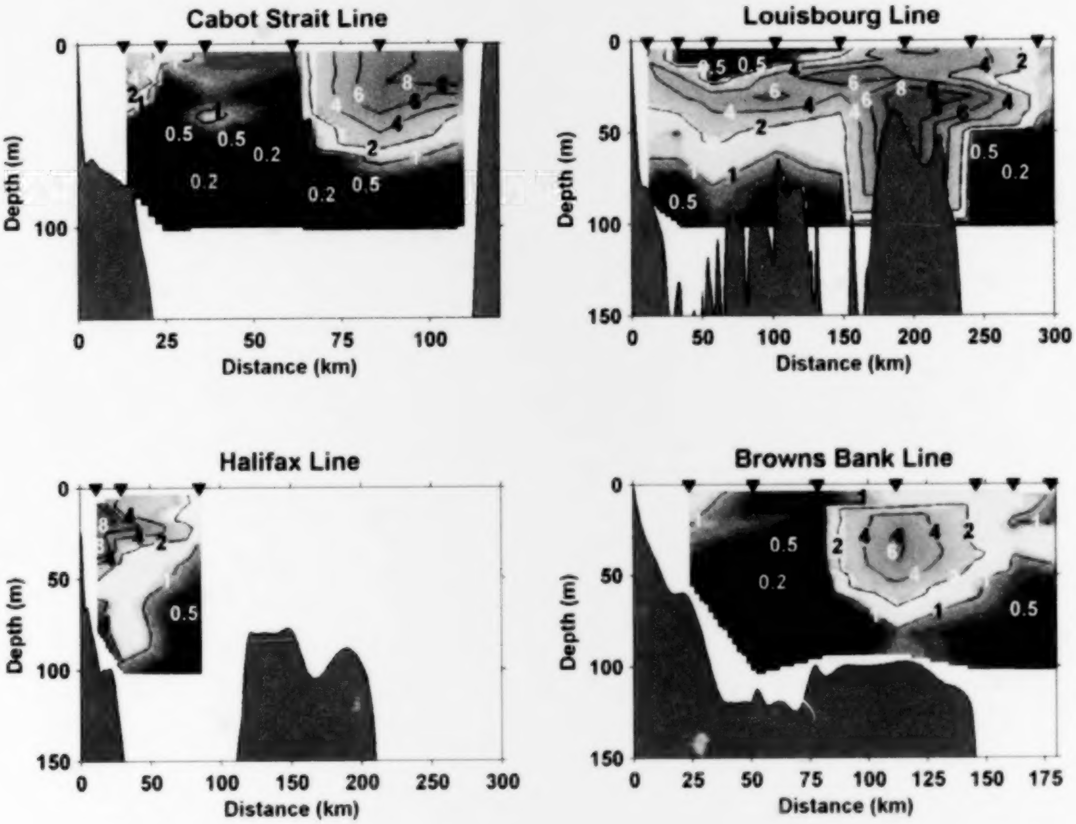
Figure 16. Time series of microplankton (phytoplankton and protists) abundance and community composition at the Maritimes fixed stations, 1999-2008.



AZMP Sections
Chlorophylle (mg m^{-3})
Cruise HUD2008004 (Spring 2008)

Cabot Strait Line	:	Apr 24
Louisbourg Line	:	Apr 22-27
Halifax Line(3 stns)	:	Apr 15
Browns Bank Line	:	Apr 17-18

Figure 17. Vertical chlorophyll structure along the Scotian Shelf sections during the spring survey in 2008.



AZMP Sections
Chlorophylle (mg m^{-3})

Cruise HUD2008004		**(Spring 2008)**
Cabot Strait Line	:	**Apr 24**
Louisbourg Line	:	**Apr 22-27**
Halifax Line(3 stns)	:	**Apr 15**
Browns Bank Line	:	**Apr 17-18**

Figure 17. Vertical chlorophyll structure along the Scotian Shelf sections during the spring survey in 2008.

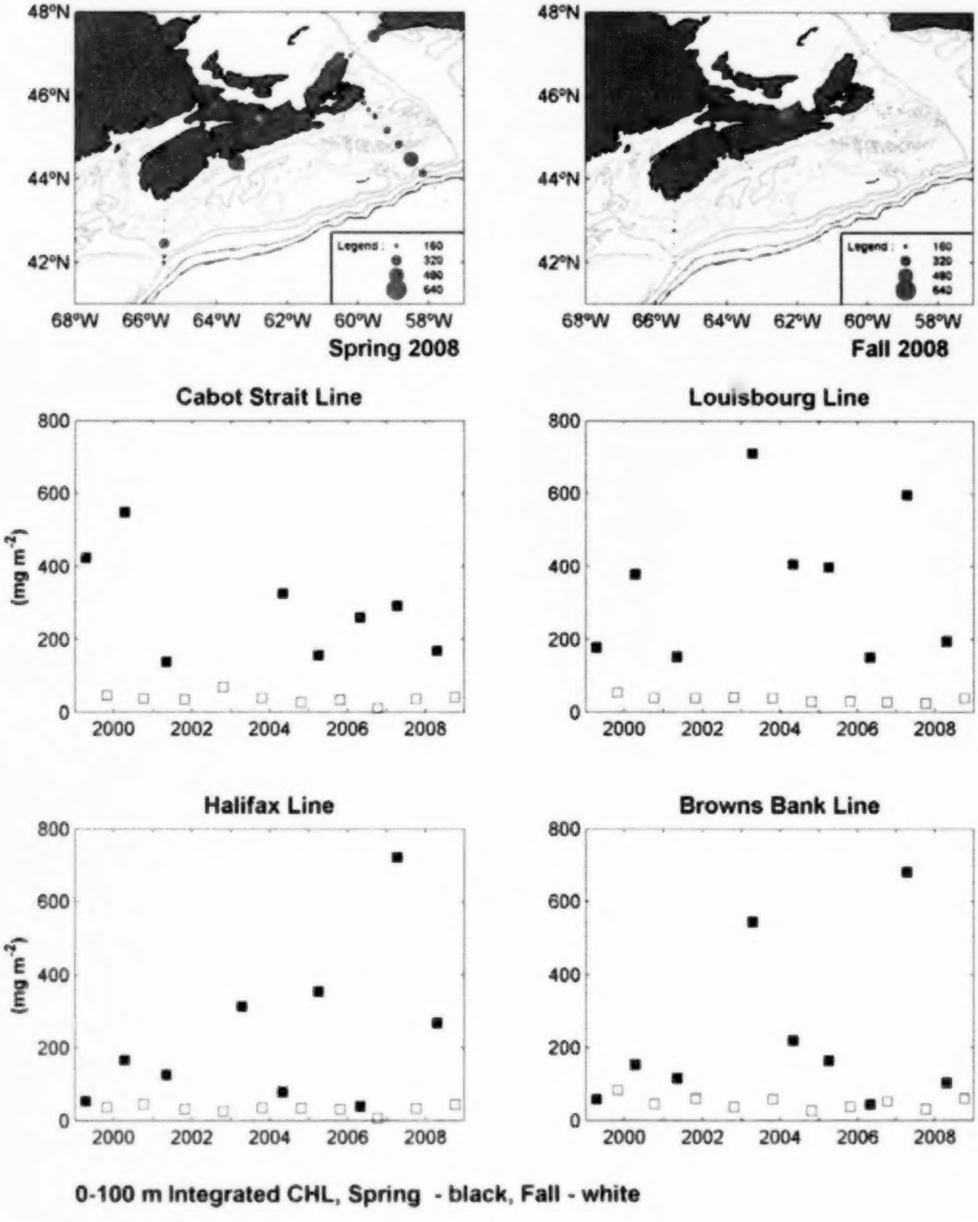


Figure 18. Time series of line-averaged inventories of chlorophyll in the upper water column (0-100 m) for the spring and fall Scotian Shelf sections, 1999-2008.

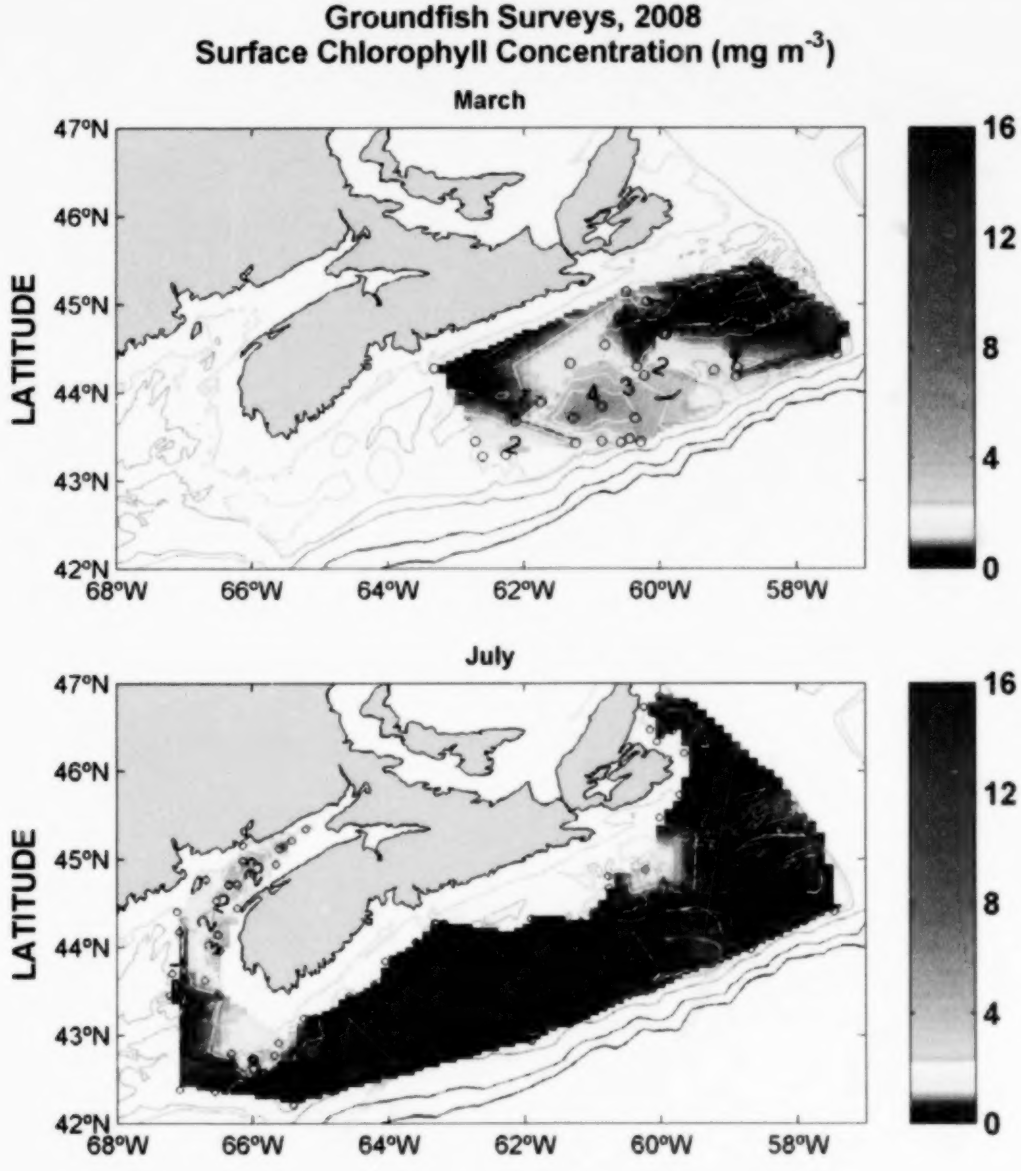


Figure 19. Surface chlorophyll concentrations on the Scotian Shelf during the annual March and July trawl (groundfish) surveys in 2008.

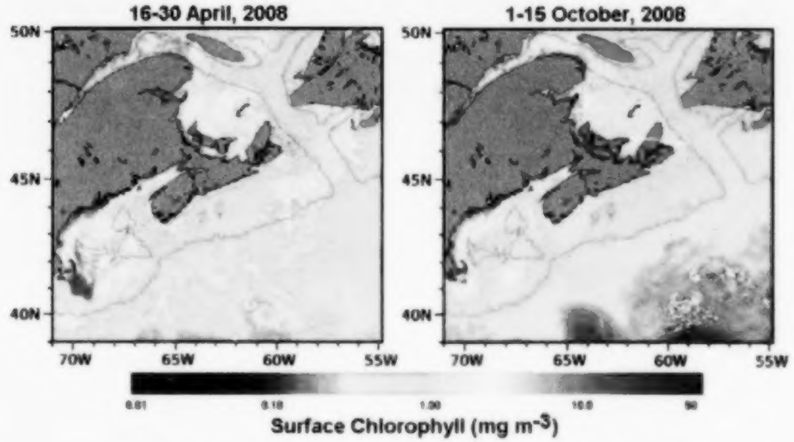


Figure 20. MODIS twice monthly composite images of surface chlorophyll in the Maritimes/Gulf regions: during the spring (April) and fall (October) shelf surveys in 2008. See Figure 2 for station locations.

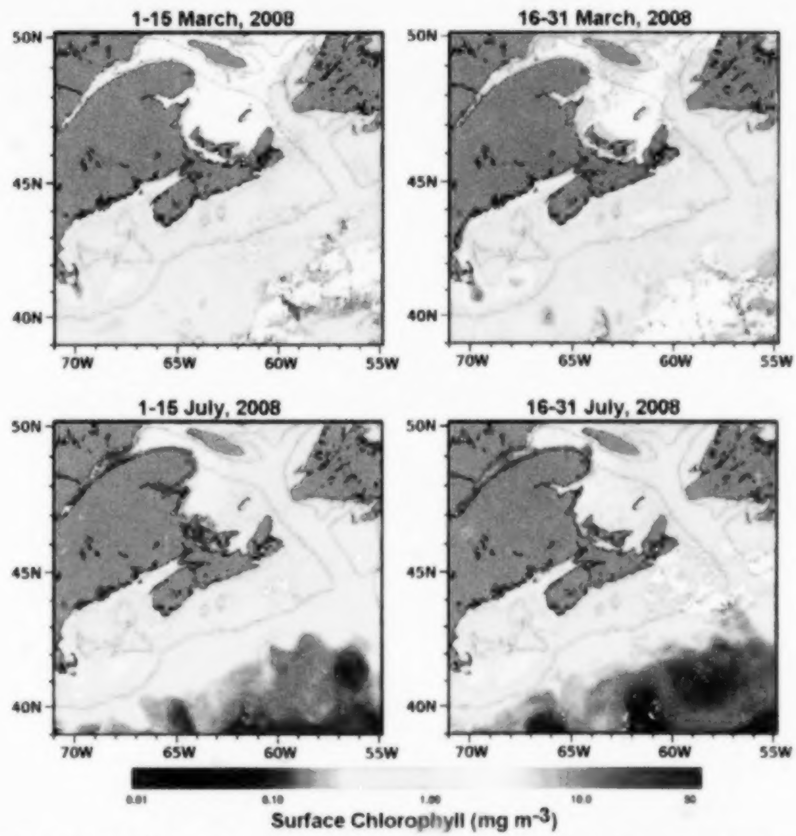


Figure 21. MODIS twice monthly composite images of surface chlorophyll in the Maritimes/Gulf regions during the winter (February), spring (March), and summer (July) trawl (groundfish) surveys in 2008. See Figure 3 for station locations.

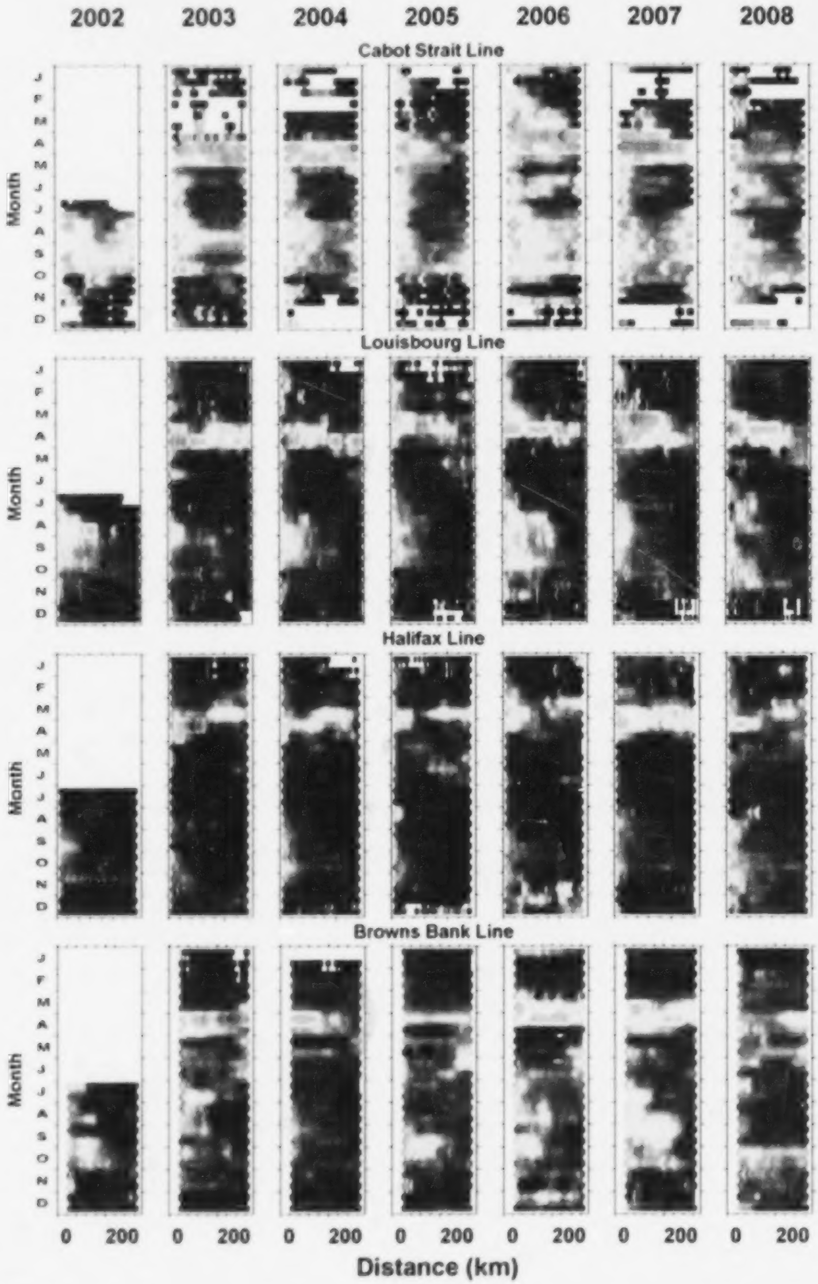


Figure 22. Time series of surface chlorophyll concentrations (mg m^{-3}), from MODIS twice monthly ocean colour data, along the Maritimes sections (see Figure 1), 1999-2008. Horizontal axes running south to north (Cabot line) or west to east (Louisbourg, Halifax, Browns Bank lines).

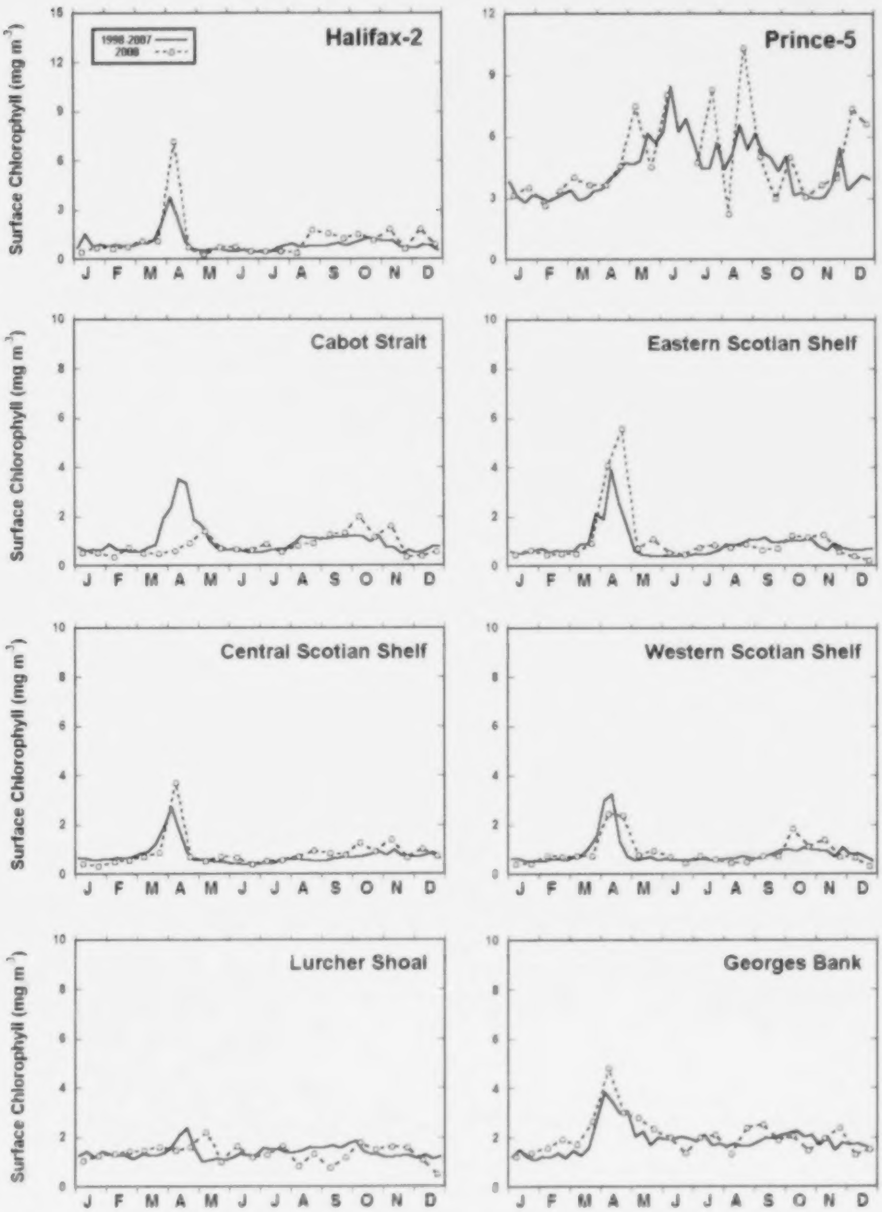


Figure 23. Seasonal variability in surface chlorophyll concentrations (from SeaWiFS 4 km weekly ocean colour data) for the fixed stations and statistical sub-regions of the Maritimes Region (see Figure 5). Solid lines represent mean (1998-2007) levels, dashed lines represent 2008 levels. Note: the spring and summer data gaps in the 2008 SeaWiFS data record (see Methods Section) were filled with adjusted MODIS data.

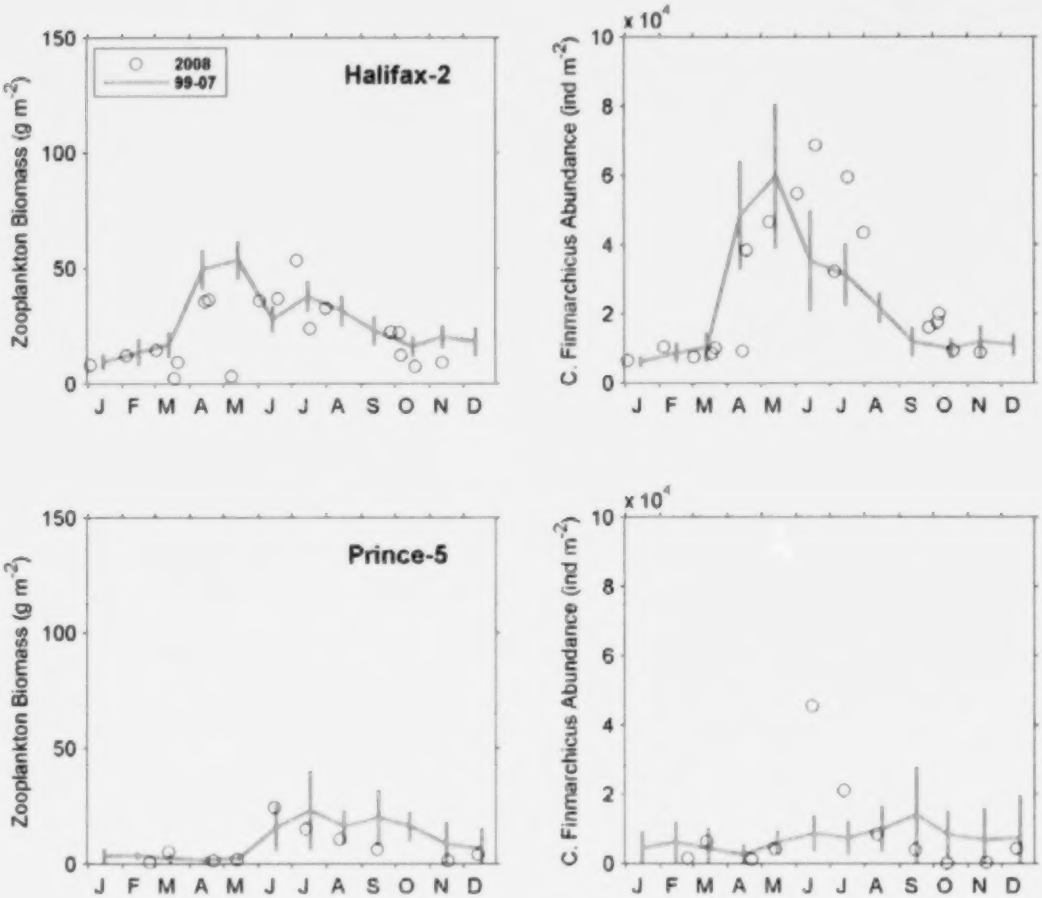


Figure 24. Comparison of 2008 data (circles) with mean conditions from 1999-2007 (solid line) at the Maritimes fixed stations. Left panels: zooplankton biomass (surface to bottom). Right panels: Calanus finmarchicus abundance (all copepodid and adult stages, surface to bottom). Vertical lines are 95% confidence limits.

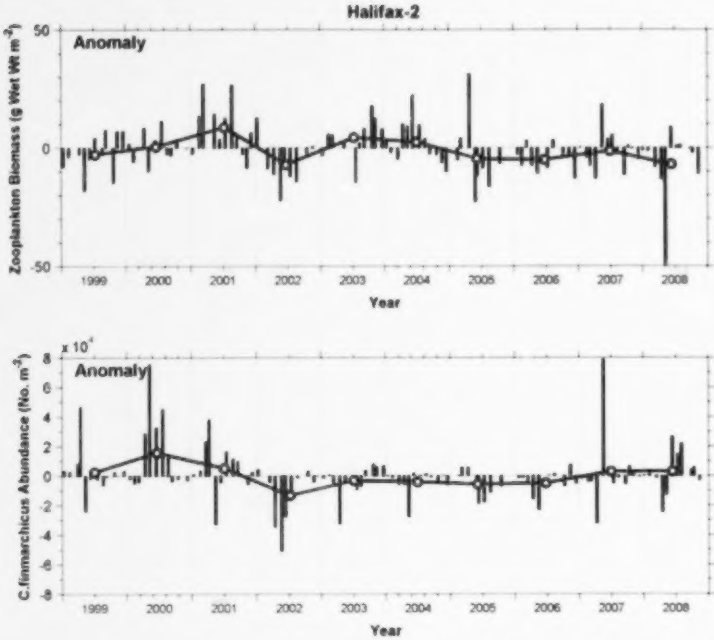


Figure 25a. Zooplankton biomass and Calanus finmarchicus abundance anomalies at Halifax-2, 1999-2008 with monthly anomalies (vertical bars) and annual anomalies (open circle). Dashed lines are overall mean levels.

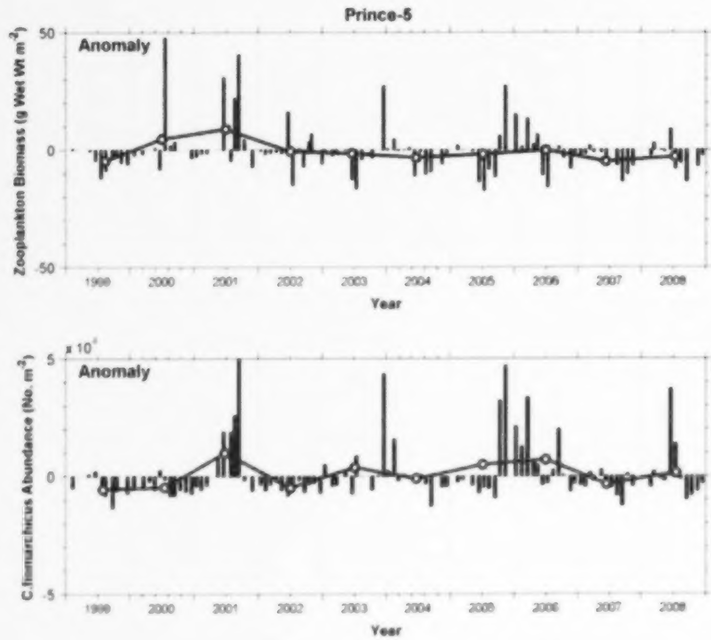


Figure 25b. Zooplankton biomass and Calanus finmarchicus abundance anomalies at Prince-5, 1999-2008, with monthly anomalies (vertical bars) and annual anomalies (open circle). Dashed lines are overall mean levels.

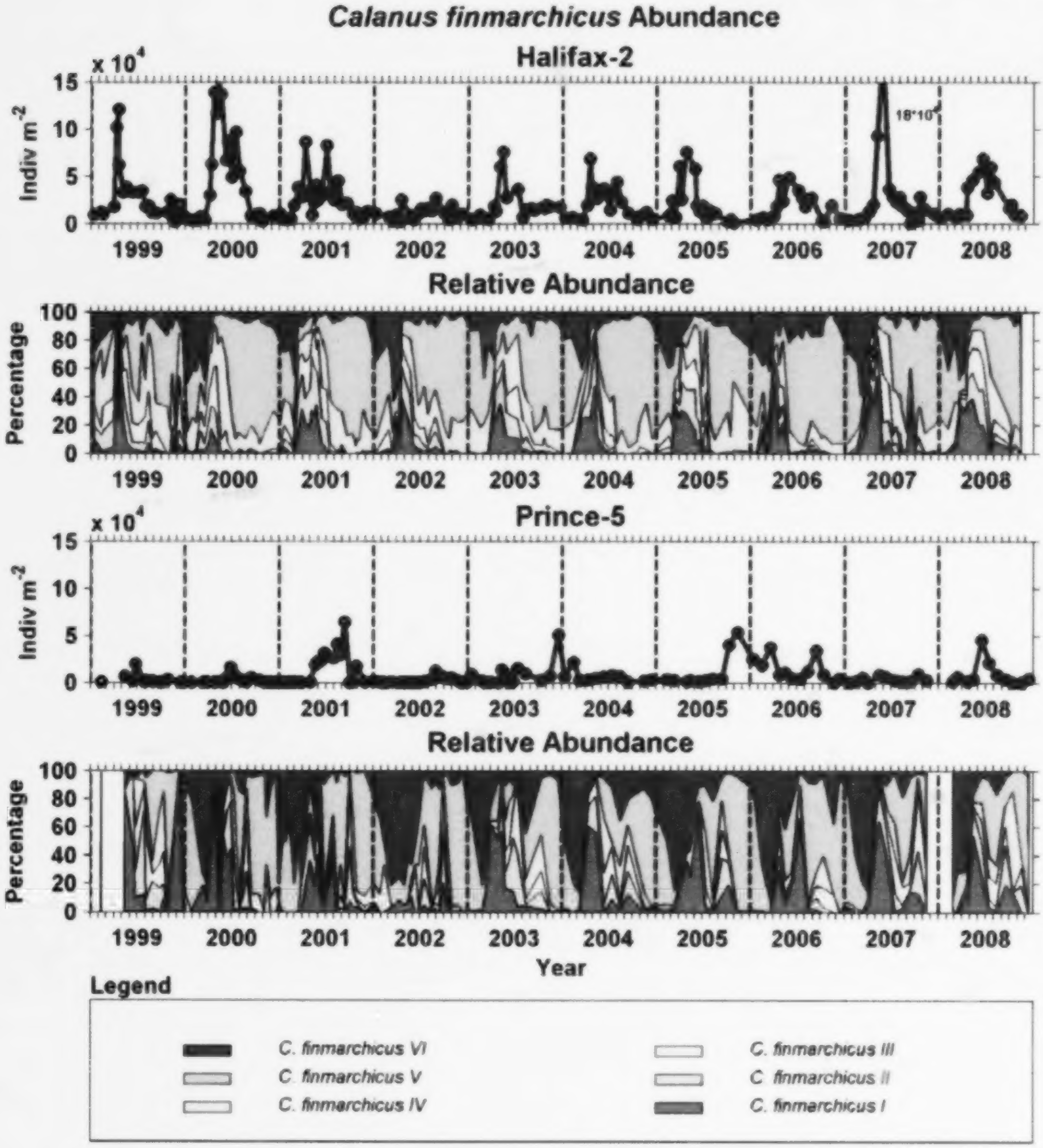


Figure 26. Time series of C. finmarchicus abundance and developmental stages at the Maritimes fixed stations, 1999-2008.

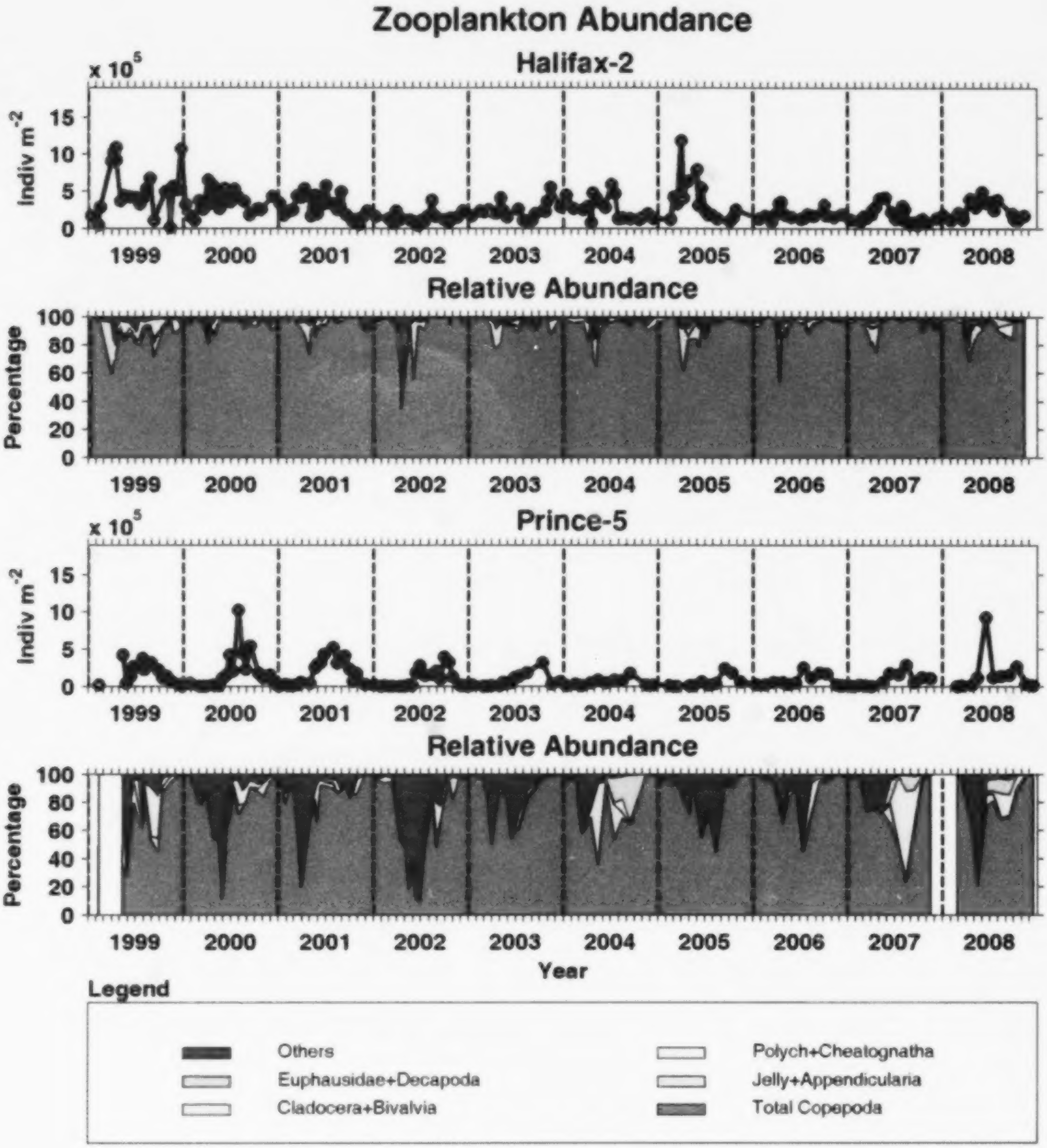


Figure 27. Time series of zooplankton (>200 μm) abundance and community composition at the Maritimes fixed stations, 1999-2008.

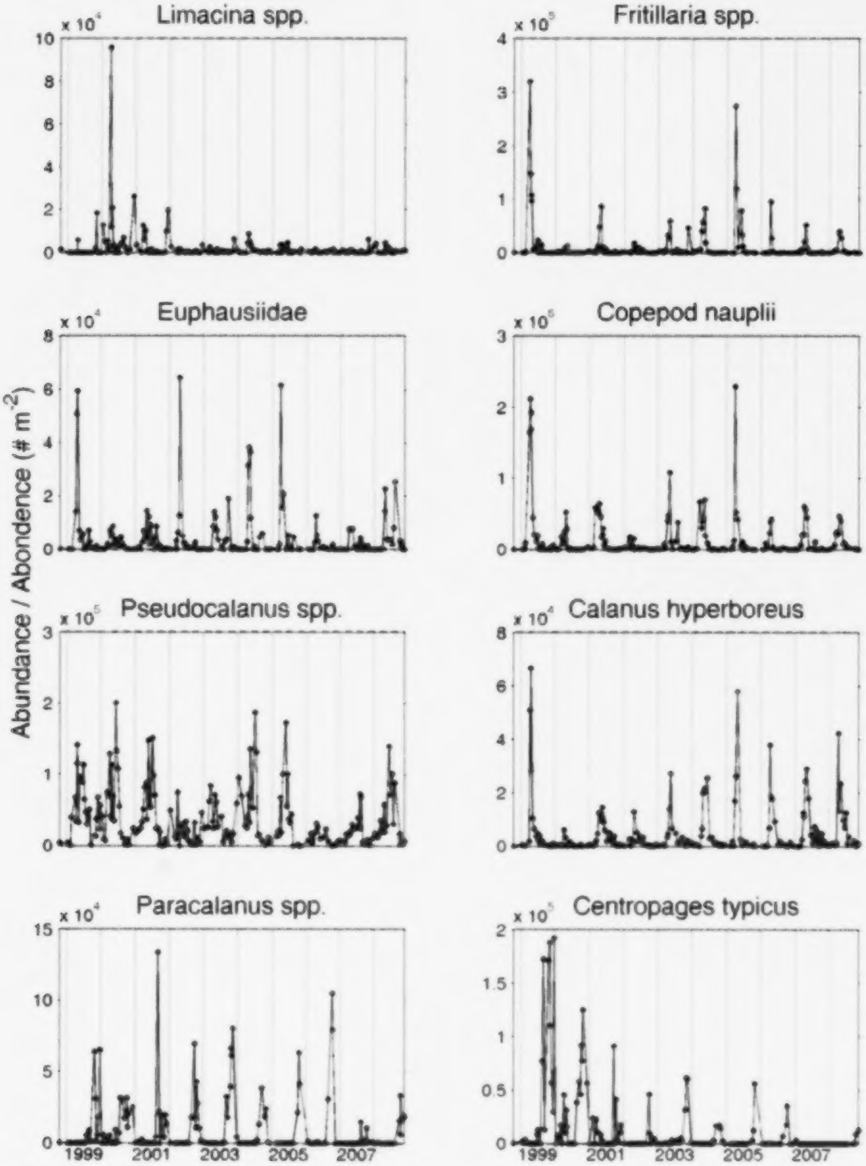


Figure 28a. Time series of 8 dominant or important zooplankton taxa from Halifax-2 for the period 1999-2008.

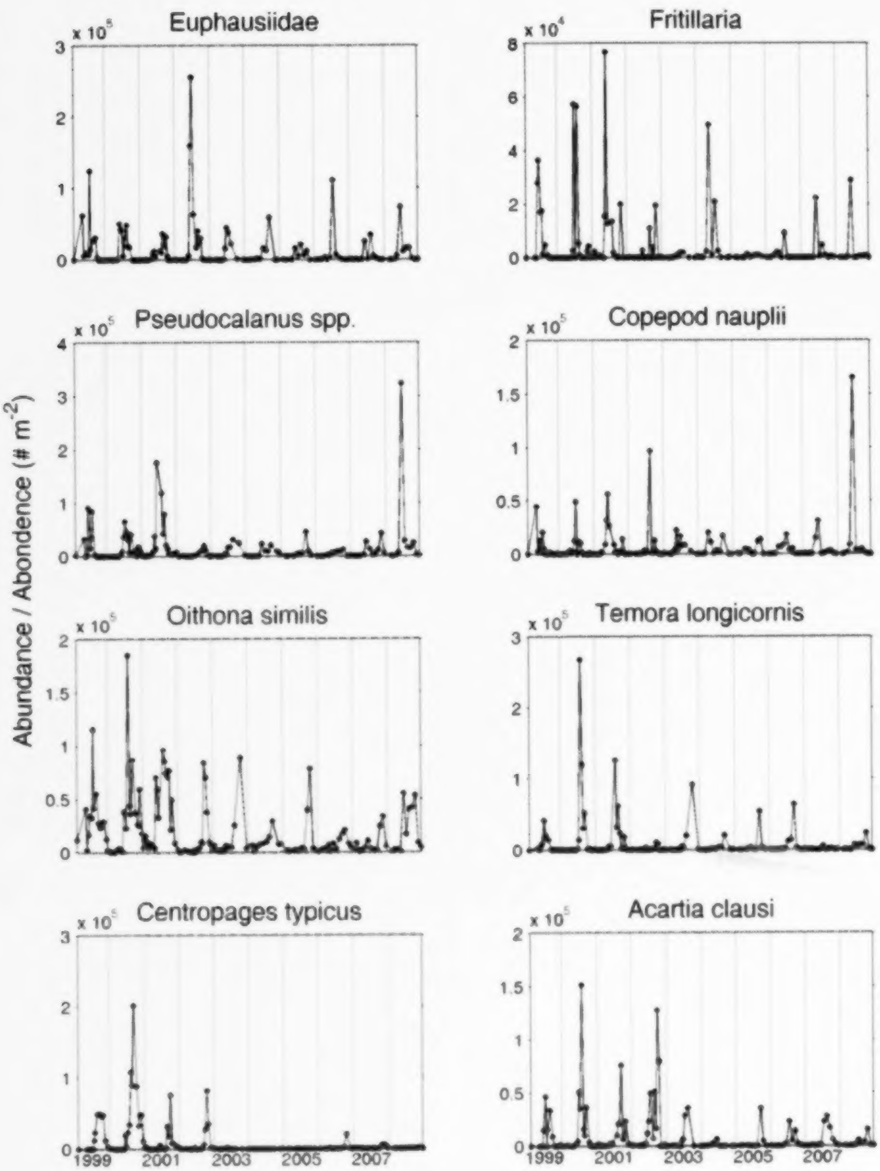


Figure 28b. Time series of 8 dominant or important zooplankton taxa from Prince-5 for the period 1999-2008.

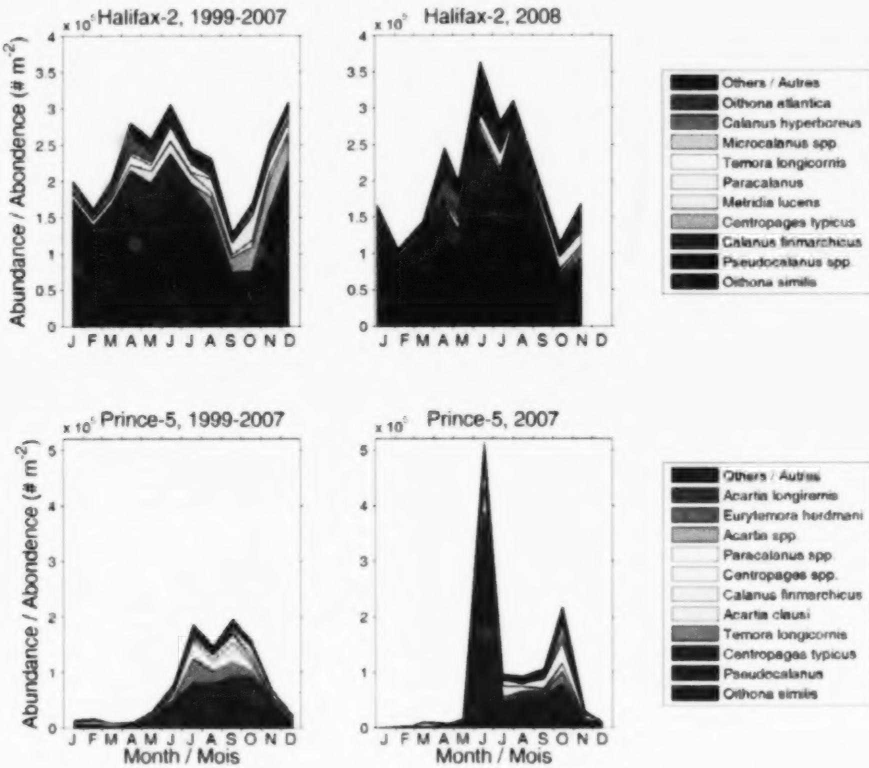


Figure 29. Seasonal variability of dominant copepods at Halifax-2 and Prince-5. The top 95% of copepods by abundance are shown individually; others are grouped as 'others.' Left-hand panels are based on average abundance of monthly mean abundance from 1999-2007. Right-hand panels are monthly mean abundance in 2008.

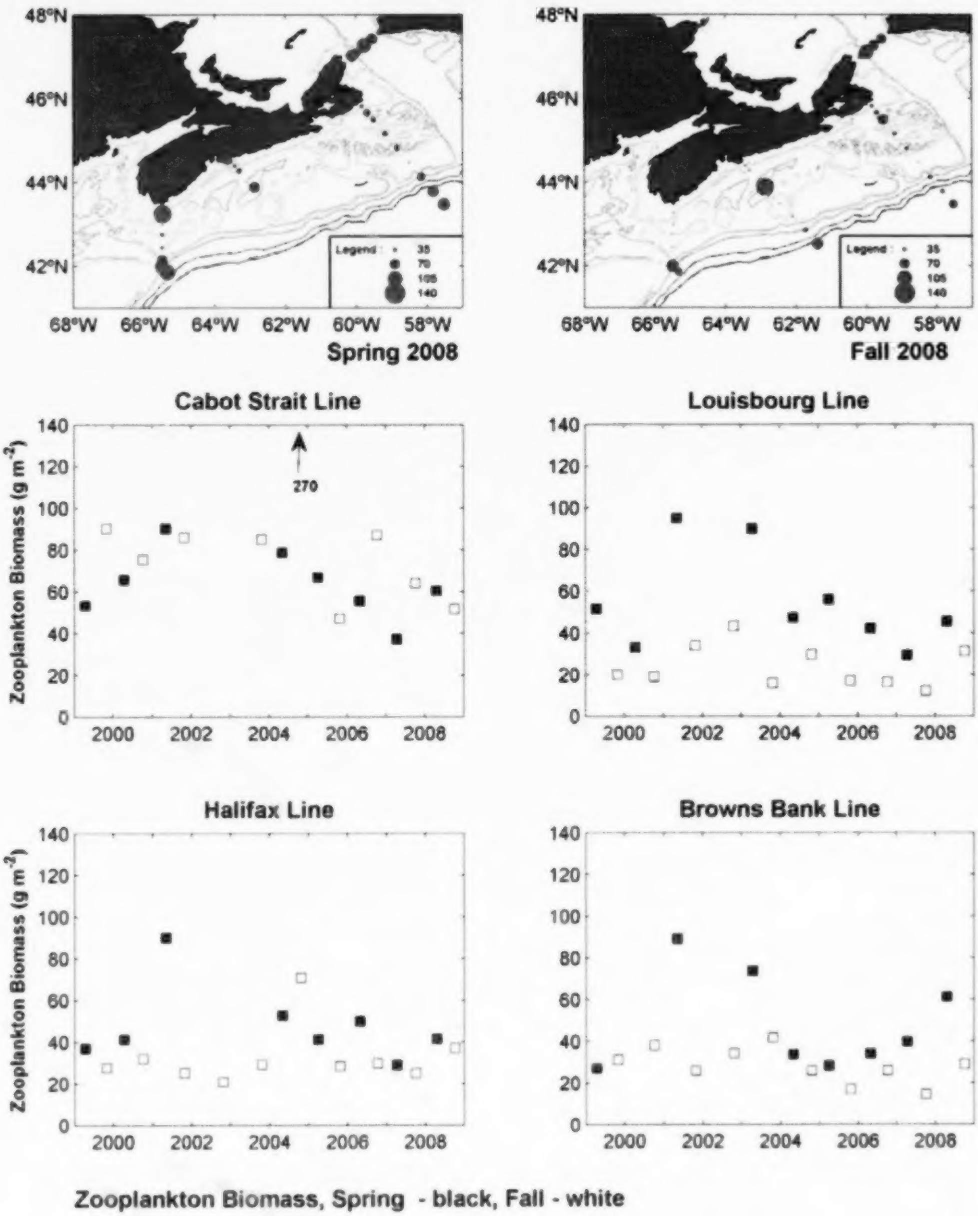


Figure 30a. Spatial distribution of zooplankton biomass (upper panels) and average zooplankton biomass on Scotian Shelf sections (lower panels) in spring and fall, 1999-2008.

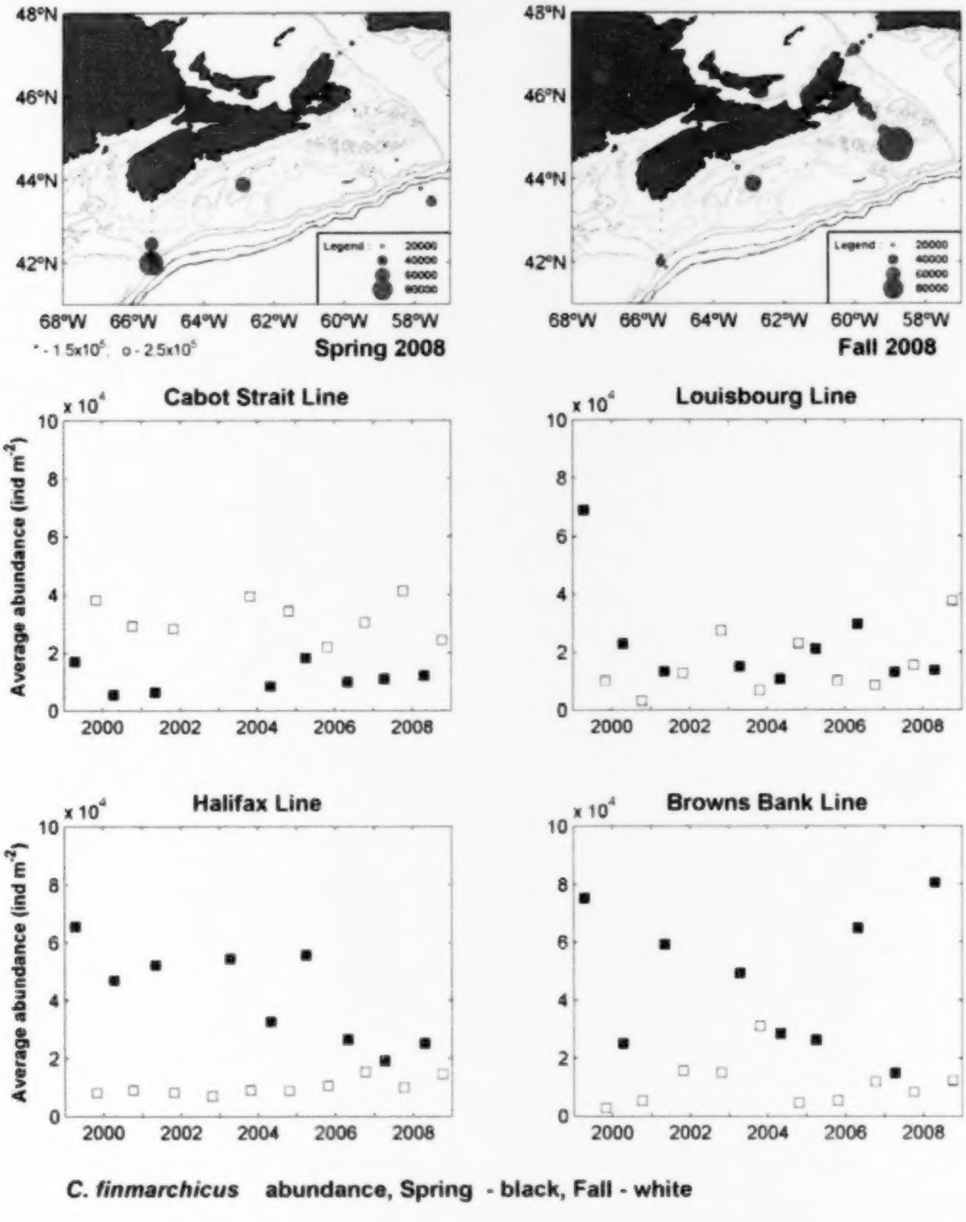


Figure 30b. Spatial distribution of Calanus finmarchicus abundance (upper panels) and average Calanus finmarchicus abundance on Scotian Shelf sections (lower panels) in spring and fall, 1999-2008.

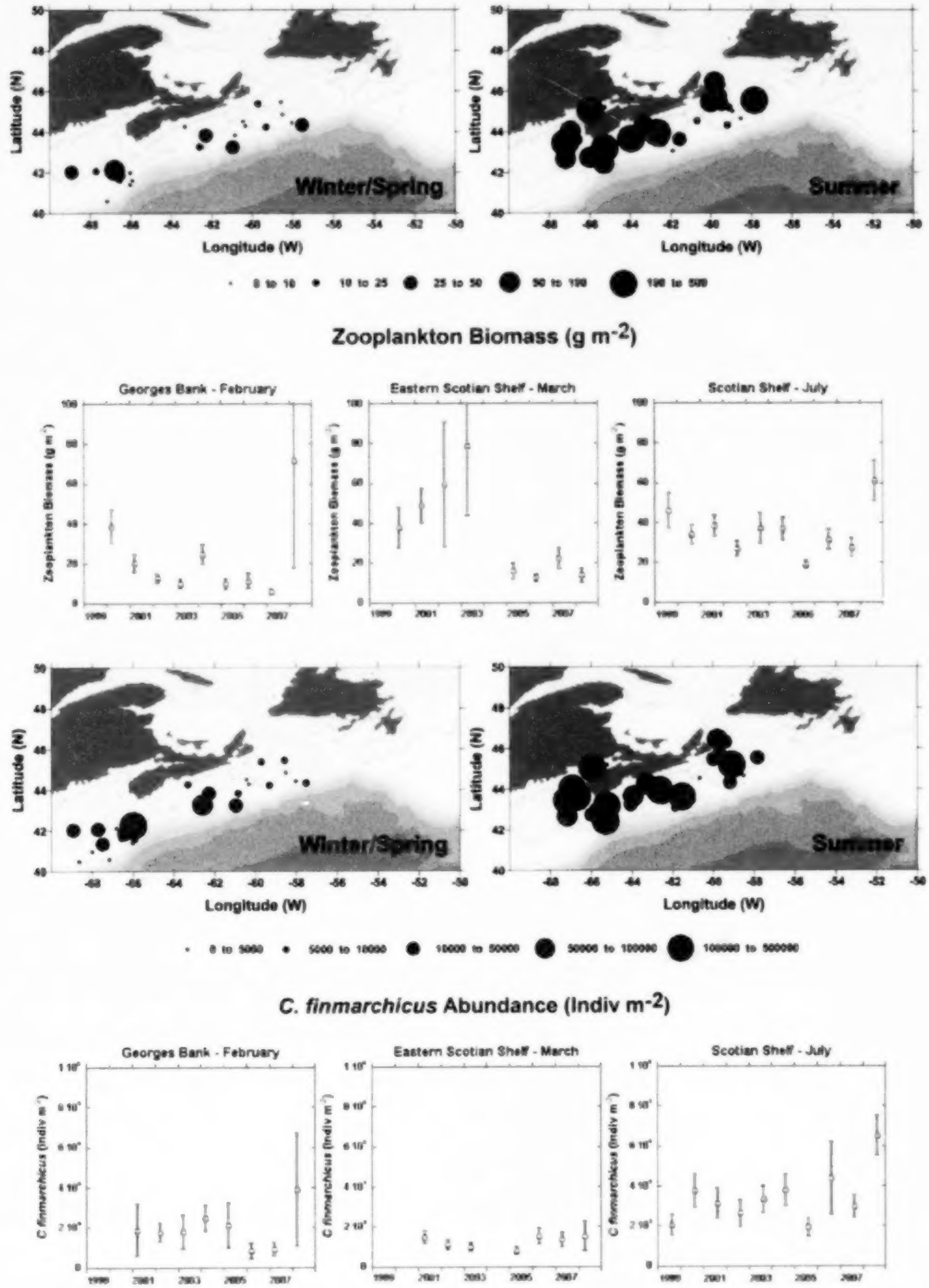


Figure 31. Zooplankton biomass and Calanus finmarchicus abundance from trawl (groundfish) surveys on Georges Bank (February), the eastern Scotian Shelf (March) and the Scotian Shelf and eastern Gulf of Maine (summer): upper panels in each set show 2008 spatial distributions, lower panels in each set show survey mean biomass or abundance, 1999-2008 (vertical bars are standard errors).

Figure 31. Zooplankton biomass and Calanus finmarchicus abundance from trawl (groundfish) surveys on Georges Bank (February), the eastern Scotian Shelf (March) and the Scotian Shelf and eastern Gulf of Maine (summer): upper panels in each set show 2008 spatial distributions, lower panels in each set show survey mean biomass or abundance, 1999-2008 (vertical bars are standard errors).

Figure 32. Maritimes Region scorecard: time series of chemical and biological variables, 1999-2008. A grey cell indicates missing data. Red cells indicate higher than normal nutrient, phytoplankton, zooplankton levels or later and longer than normal duration of phytoplankton blooms. Blue cells indicate lower than normal nutrient, phytoplankton, zooplankton levels, or earlier and shorter than normal bloom duration. More intense colours indicate larger anomalies, in increments of ± 0.5 standard deviation of the long-term mean based on data from the reference period 1999- 2006. The numbers in the cells are the anomaly values (differences from the long-term means divided by the standard deviations). CSL: Cabot Strait Line; LBL: Louisbourg Line; HL: Halifax Line; BBL: Browns Bank Line.

Taxon / Group	Location	Season / metric	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean ± s.d
Zoop Biomass	ESS	spring		-0.4	1.7			[illegible]	0.3	-0.2	-0.4	-0.2	51 ± 18
	WSS		[illegible]		2.6			-0.4	-0.7	-0.4	-0.4	0.4	49 ± 15
	ESS	summer	2.4	0.7		-0.5	[illegible]	[illegible]	-2.4	-0.5	-0.8	2.9	44 ± 10
	WSG		-0.3	-0.2	-0.1	-0.3	0.4	0.2	-0.3	-0.1	0.0	0.7	26 ± 33
	ESS	fall	-0.7	[illegible]	-0.1		-0.1	7.7	-2.5	0.0	[illegible]	-1.8	57 ± 11
	WSS		0.5	0.0	-0.7	0.1	0.1	[illegible]	-0.8	0.2	-0.3	-0.2	36 ± 18
	Hfx-2	magnitude	-0.7	0.1	0.8	[illegible]	0.0	0.4	1.7	-0.5	[illegible]	[illegible]	56 ± 15
		timing	-0.9	-0.9	0.2	-0.9	0.2	0.2	-0.9	0.2	0.2	2.4	4.8 ± 0.9
	P-5	magnitude		1.9	[illegible]	-0.1	0.0	-0.6	0.1	-0.7	[illegible]	-0.5	34 ± 20
		timing		-0.8	0.3	[illegible]	1.7	-0.8	1.2	0.3	-0.2	[illegible]	8.3 ± 2.1
C. finmarchicus	ESS	spring	1.6	-0.6	[illegible]			-0.7	0.9	0.5	-0.4	-0.4	4.0 ± 0.2
	WSS		1.4	-0.2	0.9		0.5	[illegible]	-0.3	0.4	-2.1	0.0	4.5 ± 0.2
	ESS	summer	[illegible]	-0.2	-1.8	-0.8	1.3	0.4	-0.2	0.7	0.4	[illegible]	3.8 ± 0.4
	WSG		[illegible]	1.2		0.3	0.0	0.7	[illegible]	-0.5	-0.1	[illegible]	4.4 ± 0.1
	ESS	fall	0.1	-1.9	0.3		-0.4	1.4	-0.8	-0.3	0.3	[illegible]	4.1 ± 0.1
	WSS		-2.5	-0.2	0.0	0.5	1.0	-0.8	0.0	0.4	0.6	0.8	3.4 ± 0.4
	Hfx-2	magnitude	0.6	1.2	0.1	-1.8	-0.1	-0.3	-0.1	-1.0	1.5	-0.3	4.9 ± 0.2
		timing	-0.7	-0.3	-0.9	2.5	-0.2	[illegible]	[illegible]	0.1	0.1	0.5	144 ± 50
	P-5	magnitude		-0.8	[illegible]	[illegible]	0.8	-0.4	0.9	0.4	-1.6	0.7	4.5 ± 0.3
		timing		-0.3	0.4	0.3	[illegible]	-1.6	1.0	[illegible]	0.7	-0.4	215 ± 104
Pseudocalanus spp.	ESS	sp., su.	[illegible]	[illegible]	1.7			0.3	-0.3	0.1	-0.5	1.0	4.4 ± 0.1
	WSS		1.4	0.8			-0.4	0.5	0.2	-1.9	-0.6	0.0	4.1 ± 0.3
	Hfx-2	magnitude	0.4	1.0	0.5	-0.7	-0.5	0.9	0.8	-2.2	-0.7	0.4	5.0 ± 0.3
		timing	-0.8	0.4	0.9	[illegible]	[illegible]	1.0	0.2	-0.7	1.6	0.3	144 ± 45
	P-5	magnitude		0.3	1.2	-0.8	-0.4	-0.7	-0.1	[illegible]	-0.1	1.8	4.7 ± 0.5
		timing		-0.6	[illegible]	1.0	-0.1	[illegible]	0.5	0.9	1.5	[illegible]	230 ± 61
Oithona similis	ESS	sp., su., fall	1.8	[illegible]	-0.6			0.5	-0.4	-0.3	-0.8	0.9	4.8 ± 0.1
	WSS		1.6	1.4			-0.5	-0.4	0.0	-0.6	[illegible]	0.1	4.6 ± 0.2
Temora longicornis	ESS	sp., su., fall	-0.3	-0.8	0.3			0.9	-0.7	[illegible]	-1.5	1.0	3.0 ± 0.4
	WSS		1.0	[illegible]			[illegible]	0.8	0.6	-0.5	-1.5	-0.1	1.8 ± 0.7
	Hfx-2	magnitude	[illegible]	0.2	-0.4	[illegible]	-0.4	1.1	[illegible]	0.1	-1.8	0.4	4.4 ± 0.4
	P-5	magnitude		1.5	0.9	[illegible]	0.7	-0.5	0.2	0.4	-1.7	-0.4	4.6 ± 0.5
C. hyperboreus	ESS	spring	0.5	-1.8	0.2			0.2	0.4	0.5	0.9	[illegible]	3.9 ± 0.2
	WSS		-1.9	[illegible]	1.0		0.5	1.0	0.2	0.0	0.8	-0.6	3.2 ± 0.6
	Hfx-2	magnitude	[illegible]	-2.0	-0.8	-0.5	0.1	0.0	[illegible]	0.5	0.1	0.7	4.4 ± 0.3
C. glacialis	ESS	spring		-0.2	0.0			[illegible]	1.6	0.2	0.7	-1.6	3.2 ± 0.4
	WSS		-0.6	-1.8	-0.4		1.2	0.1	1.0	-0.4	1.2	-0.4	2.2 ± 0.8
	Hfx-2	magnitude	0.8	-1.7	0.4	-1.6	0.2	-0.7	0.7	0.8	0.4	0.9	3.9 ± 0.3
Warm shelf spp.	ESS	fall	0.8	0.9	0.4		-0.2	-1.8	0.5	0.1	[illegible]	0.3	3.8 ± 0.7
	WSS		[illegible]	0.8	0.1	0.0	0.5	-1.9	-0.4	-0.1	[illegible]	0.8	4.2 ± 0.4
	Hfx-2	magnitude	[illegible]	0.5	0.9	0.2	0.5	-0.8	0.0	0.3	-2.2	-0.7	5.0 ± 0.3
	P-5	magnitude		1.8	0.5	0.7	[illegible]	[illegible]	[illegible]	0.6	-0.1	-0.1	4.7 ± 0.4
Warm offshore spp.	ESS	fall	[illegible]	0.4	-0.9		-0.5	0.0	0.0	2.1	0.8	-0.1	1.2 ± 0.3
	WSS		[illegible]	0.5	[illegible]	1.0	0.7	[illegible]	-0.5	1.2	-0.8	[illegible]	3.1 ± 0.5
Cold offshore spp.	ESS	sp., su., fall	-0.3	-0.5	-0.5			0.7	[illegible]	1.6	1.1	-0.9	1.6 ± 0.2
	WSS		0.4	0.0			0.3	[illegible]	[illegible]	0.9	1.5	-0.6	1.1 ± 0.3
Appendicularians	ESS	spring	1.3	[illegible]	0.5			0.2	0.3	1.0	[illegible]	-0.9	3.7 ± 0.7
	WSS		-0.6	0.3	0.1		[illegible]	0.5	1.2	-1.9	-1.0	0.2	3.8 ± 0.7
	Hfx-2	magnitude	1.6	-1.8	0.2	-0.8	-0.3	0.1	[illegible]	0.4	-0.5	-0.3	4.9 ± 0.4
Metridia lucens	ESS	sp., su., fall	-0.1	0.8	-2.0			-0.6	0.4	[illegible]	0.1	0.0	2.6 ± 0.3
	WSS		1.6	[illegible]			-1.0	[illegible]	-0.3	0.4	-0.4	-0.3	3.3 ± 0.4
Limacina	ESS	sp., su., fall	[illegible]	-1.0	0.8			1.6	-0.2	-0.7	-0.7	-0.8	2.1 ± 0.4
	WSS		1.1	1.8			-0.7	0.0	[illegible]	-0.8	-0.8	0.3	1.8 ± 0.8

Anomaly Scale
> 2.5
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
-0.5 to 1
-1 to -0.5
-1.5 to -1
-2 to -1.5
< -2.5

Figure 33. Maritimes Region zooplankton scorecard: time series of zooplankton metrics, 1999-2008. A white cell indicates missing data. Red cells indicate higher than normal zooplankton levels or later than normal peaks. Blue cells indicate lower than normal zooplankton levels or earlier than normal peaks. More intense colours indicate larger anomalies, in increments of ± 0.5 standard deviation of the long-term mean based on data from the reference period 1999- 2007. The numbers in the cells are the anomaly values (differences from the long-term means divided by the standard deviations). ESS: eastern Scotian Shelf; WSS: western Scotian Shelf; WSG: western Scotian Shelf and Gulf of Maine.

Figure 32. Maritimes Region scorecard: time series of chemical and biological variables, 1999-2008. A grey cell indicates missing data. Red cells indicate higher than normal nutrient, phytoplankton, zooplankton levels or later and longer than normal duration of phytoplankton blooms. Blue cells indicate lower than normal nutrient, phytoplankton, zooplankton levels, or earlier and shorter than normal bloom duration. More intense colours indicate larger anomalies, in increments of ± 0.5 standard deviation of the long-term mean based on data from the reference period 1999- 2006. The numbers in the cells are the anomaly values (differences from the long-term means divided by the standard deviations). CSL: Cabot Strait Line; LBL: Louisbourg Line; HL: Halifax Line; BBL: Browns Bank Line.

Taxon / Group	Location	Season / metric	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean	±	s.d
Zoop Biomass	ESS	spring		-0.4	[illegible]			-0.8	0.3	-0.2	-0.4	-0.2	51	±	18
	WSS		-1.2		2.6			-0.4	-0.7	-0.4	-0.4	0.4	49	±	15
	ESS	summer	2.4	0.7		-0.5	-1.2	-0.6	-2.4	-0.5	-0.8	2.9	44	±	10
	WSG		-0.3	-0.2	-0.1	-0.3	0.4	0.2	-0.3	-0.1	0.0	0.7	26	±	33
	ESS	fall	-0.7	-1.2	-0.1		-0.1	7.7	-2.5	0.0	-1.3	-1.8	57	±	11
	WSS		0.5	0.0	-0.7	0.1	0.1	1.2	-0.8	0.2	-0.3	-0.2	36	±	18
	Hfx-2	magnitude	-0.7	0.1	0.8	-1.2	0.0	0.4	[illegible]	-0.9	1.1	-1.2	56	±	15
		timing	-0.9	-0.9	0.2	-0.9	0.2	0.2	-0.9	0.2	0.2	2.4	4.8	±	0.9
	P-5	magnitude		[illegible]	1.3	-0.1	0.0	-0.6	0.1	-0.7	-1.3	-0.5	34	±	20
		timing		-0.6	0.3	-1.1	[illegible]	-0.6	1.3	0.3	-0.2	-1.1	8.3	±	2.1
C. finmarchicus	ESS	spring	[illegible]	-0.6	-1.2			-0.7	0.9	0.9	-0.4	-0.4	4.0	±	0.2
	WSS		1.4	-0.2	0.9		0.5	-0.5	-0.3	0.4	-2.1	0.0	4.5	±	0.2
	ESS	summer	-1.0	-0.2	-1.8	-0.8	1.2	0.4	-0.2	0.7	0.4	1.3	3.8	±	0.4
	WSG		-1.3	1.2		0.3	0.0	0.7	-1.3	-0.9	-0.1	1.3	4.4	±	0.1
	ESS	fall	0.1	-1.9	0.3		-0.4	1.4	-0.6	-0.3	0.3	1.2	4.1	±	0.1
	WSS		-2.5	-0.2	0.0	0.5	1.0	-0.6	0.0	0.4	0.6	0.8	3.4	±	0.4
	Hfx-2	magnitude		1.2	0.1	-1.8	-0.1	-0.3	-0.1	-1.0	[illegible]	-0.3	4.9	±	0.2
		timing	[illegible]	-0.3	-0.9	2.5	-0.2	-0.7	-0.5	0.1	0.1	0.5	144	±	50
	P-5	magnitude		-0.8	1.1	-1.2	0.8	-0.4	0.9	0.4	-1.6	0.7	4.5	±	0.3
		timing		-0.3	0.4	0.3	1.3	-1.6	1.0	-1.3	0.7	-0.4	215	±	104
Pseudocalanus spp	ESS	sp su	-1.1	-1.2	[illegible]			0.3	-0.3	0.1	-0.5	1.0	4.4	±	0.1
	WSS		1.4	0.8			-0.4	0.5	0.2	-1.9	-0.6	0.0	4.1	±	0.3
	Hfx-2	magnitude	0.4	1.0	0.5	-0.7	-0.5	0.9	0.8	-2.2	-0.7	0.4	5.0	±	0.3
		timing	-0.8	0.4	0.9	-1.2	-1.4	1.0	0.2	-0.7	[illegible]	0.3	144	±	45
	P-5	magnitude		0.3	1.2	-0.8	-0.4	-0.7	-0.1	-1.3	-0.1	[illegible]	4.7	±	0.5
		timing		-0.6	-1.1	1.0	-0.1	-1.1	0.5	0.9	1.5	-1.0	230	±	61
Oithona similis	ESS	sp su fall	[illegible]	-1.2	-0.6			0.5	-0.4	-0.3	-0.8	0.9	4.8	±	0.1
	WSS		[illegible]	1.4			-0.8	-0.4	0.0	-0.6	-1.2	0.1	4.6	±	0.2
Temora longicornis	ESS	sp su fall	-0.3	-0.8	0.3			0.9	-0.7	1.1	-1.5	1.0	3.0	±	0.4
	WSS		1.0	1.0			-1.2	0.8	0.6	-0.5	-1.5	-0.1	1.8	±	0.7
	Hfx-2	magnitude	1.1	0.2	-0.4	-1.3	-0.4	1.1	1.0	0.1	-1.8	0.4	4.4	±	0.4
	P-5	magnitude		[illegible]	0.9	-1.0	0.7	-0.5	0.2	0.4	-1.7	-0.4	4.6	±	0.5
C. hyperboreus	ESS	spring	0.5	-1.8	0.2			0.2	0.4	0.9	0.9	-1.3	3.9	±	0.2
	WSS		-1.9	-1.1	1.0		0.5	1.0	0.2	0.0	0.8	-0.5	3.2	±	0.6
	Hfx-2	magnitude	1.3	-2.0	-0.8	-0.9	0.1	0.0	1.1	0.5	0.1	0.7	4.4	±	0.3
C. glacialis	ESS	spring		-0.2	0.0			-1.0	[illegible]	0.2	0.7	-1.6	3.2	±	0.4
	WSS		-0.6	-1.8	-0.4		1.2	0.1	1.0	-0.4	1.2	-0.4	2.2	±	0.8
	Hfx-2	magnitude	0.8	-1.7	0.4	-1.6	0.2	-0.7	0.7	0.8	0.4	0.9	3.9	±	0.3
Warm shelf spp	ESS	fall	0.8	0.9	0.4		-0.2	-1.8	0.9	0.1	-1.5	0.3	3.8	±	0.7
	WSS		1.5	0.8	0.1	0.0	0.5	-1.9	-0.4	-0.1	-1.3	0.8	4.2	±	0.4
	Hfx-2	magnitude	1.3	0.5	0.9	0.2	0.5	-0.8	0.0	0.3	-2.2	-0.7	5.0	±	0.3
	P-5	magnitude		[illegible]	0.5	0.7	-1.0	-1.2	-1.2	0.6	-0.1	-0.1	4.7	±	0.4
Warm offshore spp	ESS	fall	-1.3	0.4	-0.9		-0.6	0.0	0.0	2.1	0.6	-0.1	1.2	±	0.3
	WSS		1.1	0.5	-1.2	1.0	0.7	-1.1	-0.5	1.2	-0.5	-1.1	3.1	±	0.5
Cold offshore spp	ESS	sp su fall	-0.3	-0.6	-0.5			0.7	-1.1	[illegible]	1.1	-0.9	1.6	±	0.2
	WSS		0.4	0.0			0.3	-1.1	-1.4	0.9	[illegible]	-0.6	1.1	±	0.3
Appendicularians	ESS	spring	1.3	-1.2	0.5			0.2	0.3	1.0	-1.5	-0.6	3.7	±	0.7
	WSS		-0.6	0.3	0.1		1.1	0.5	1.2	-1.9	-1.0	0.2	3.8	±	0.7
	Hfx-2	magnitude	[illegible]	-1.8	0.2	-0.8	-0.3	0.1	1.5	0.4	-0.5	-0.3	4.9	±	0.4
Metridia lucens	ESS	sp su fall	-0.1	0.8	-2.0			-0.6	0.4	1.4	0.1	0.0	2.6	±	0.3
	WSS		[illegible]	1.3			-1.0	-1.2	-0.3	0.4	-0.4	-0.3	3.3	±	0.4
Limacina	ESS	sp su fall	1.1	-1.0	0.8			[illegible]	-0.2	-0.7	-0.7	-0.8	2.1	±	0.4
	WSS		1.1	[illegible]			-0.7	0.0	-1.2	-0.6	-0.6	0.3	1.8	±	0.8

Anomaly Scale
> 2.5
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0 to 0.5
-0.5 to 0
-1 to -0.5
-1.5 to -1
-2 to -1.5
< -2.5

Figure 33. Maritimes Region zooplankton scorecard: time series of zooplankton metrics, 1999-2008. A white cell indicates missing data. Red cells indicate higher than normal zooplankton levels or later than normal peaks. Blue cells indicate lower than normal zooplankton levels or earlier than normal peaks. More intense colours indicate larger anomalies, in increments of ± 0.5 standard deviation of the long-term mean based on data from the reference period 1999- 2007. The numbers in the cells are the anomaly values (differences from the long-term means divided by the standard deviations). ESS: eastern Scotian Shelf; WSS: western Scotian Shelf; WSG: western Scotian Shelf and Gulf of Maine.